BS EN 62493:2015

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Assessment of lighting equipment related to human exposure to electromagnetic field

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National foreword

This British Standard is the UK implementation of EN 62493:2015. It is identical to IEC 62493:2015. It supersedes BS EN 62493:2010, which will be withdrawn on 7 March 2018.

The UK participation in its preparation was entrusted to Technical Committee CPL/34, Lamps and Related Equipment.

A list of organizations represented on this committee can be obtained on request to its secretary.

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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EUROPEAN STANDARD

NORME EUROPÉENNE

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May 2015

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English Version

Assessment of lighting equipment related to human exposure to electromagnetic Field (IEC 62493:2015)

Évaluation d'un équipement d'éclairage relativement à l'exposition humaine aux champs électromagnétiques (IEC 62493:2015)

Beurteilung von Beleuchtungseinrichtungen bezüglich der Exposition von Personen gegenüber elektromagnetischen Feldern (IEC 62493:2015)

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European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

CEN-CENELEC Management Centre: Avenue Marnix 17, B-1000 Brussels

Foreword

The text of document 34/222/FDIS, future edition 2 of IEC 62493, prepared by IEC/TC 34 "Lamps and related equipment" was submitted to the IEC-CENELEC parallel vote and approved by CENELEC as EN 62493:2015.

The following dates are fixed:

• latest date by which the document has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2016-01-14
• latest date by which the national standards conflicting with the document have to be withdrawn	(dow)	2018-04-14

This document supersedes EN 62493:2010.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

Endorsement notice

The text of the International Standard IEC 62493:2015 was approved by CENELEC as a European Standard without any modification.

In the official version, for Bibliography, the following notes have to be added for the standards indicated:

CISPR 15:2013	NOTE	Harmonized as EN 55015:2013 (not modified).
CISPR 16-1-2	NOTE	Harmonized as EN 55016-1-2.
CISPR 16-4-2:2003	NOTE	Harmonized as EN 55016-4-2:2004 [1] (not modified).
IEC 62226-2-1:2004	NOTE	Harmonized as EN 62226-2-1:2005 (not modified).

[1] Superseded by EN 55016-4-2:2011 (CISPR 16-4-2:2011).

Annex ZA
(normative)

Normative references to international publications with their corresponding European publications

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

NOTE 1 When an International Publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

NOTE 2 Up-to-date information on the latest versions of the European Standards listed in this annex is available here: www.cenelec.eu

Publication	Year	Title	EN/HD	Year
IEC 62209-2	2010	Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices - Human models, instrumentation, and procedures - Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)	EN 62209-2	2010
IEC 62232	2011	Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure	-	-
IEC 62311 (mod)	2007	Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz)	EN 62311	2008
IEC 62479 (mod)	2010	Assessment of the compliance of low power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)	EN 62479	2010
CISPR 16-1-1	-	Specification for radio disturbance and immunity measuring apparatus and methods - Part 1-1: Radio disturbance and immunity measuring apparatus - Measuring apparatus	EN 55016-1-1	-

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

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ASSESSMENT OF LIGHTING EQUIPMENT RELATED TO HUMAN EXPOSURE TO ELECTROMAGNETIC FIELDS

FOREWORD

International Standard IEC 62493 has been prepared by IEC technical committee 34: Lamps and related equipment.

This second edition cancels and replaces the first edition published in 2009. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) identification of lighting product types deemed to comply with the standard without the need for test;

b) deletion of the need for CISPR-15-compliance as a prerequisite for IEC 62493 compliance;

c) inclusion of the consequences of the ICNIRP 2010 guidelines for (up to 100 kHz);

d) adding some guidance to the Van der Hoofden test head method to improve reproducibility of results;

e) inclusion of compliance demonstration method for products having intentional radiators.

The text of this standard is based on the following documents:

FDIS	Report on voting
34/222/FDIS	34/228/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 62493 series, published under the general title *Assessment of lighting equipment related to human exposure to electromagnetic fields*, can be found on the IEC website.

The exposure limits given in Annex C (informative) are for information only; they do not comprise an exhaustive list and are valid only in certain regions of the world. It is the responsibility of users of this standard to ensure that they use the current version of the limit values specified by the applicable national authorities.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This International Standard establishes a suitable evaluation method for the influence of the electromagnetic fields in the space around the equipment mentioned in the scope, and defines standardized operating conditions and measurement distances.

This standard is designed to assess, by measurements and/or calculations, electromagnetic (EM) fields and their potential effect on the human body by reference to exposure levels of the general public given by ICNIRP:1998 [1][1], ICNIRP 2010 [2], IEEE C95.1:2005 [3] and IEEE C95.6:2002 [4]. The exposure levels with which to comply are basic restrictions (both ICNIRP- and IEEE-based).

Based on the lighting equipment operating properties, the frequency range of the applicable basic restrictions can be limited as follows:

- internal electric field between 20 kHz and 10 MHz;
- specific absorption rate (SAR) between 100 kHz and 300 MHz;
- power density is outside the scope.

NOTE Operating frequencies of lighting equipment are higher than 20 kHz to avoid audible noise and infrared interference. Frequency contributions above 300 MHz can be neglected.

This standard is not meant to supplant definitions and procedures specified in exposure standards, but it is aimed at supplementing the procedure already specified for compliance with exposure.

1 Numbers in square brackets refer to the Bibliography.

ASSESSMENT OF LIGHTING EQUIPMENT RELATED TO HUMAN EXPOSURE TO ELECTROMAGNETIC FIELDS

1 Scope

This International Standard applies to the assessment of lighting equipment related to human exposure to electromagnetic fields. The assessment consists of the induced internal electric field for frequencies from 20 kHz to 10 MHz and the specific absorption rate (SAR) for frequencies from 100 kHz to 300 MHz around lighting equipment.

Included in the scope of this standard are:

– all lighting equipment with a primary function of generating and/or distributing light intended for illumination purposes, and intended either for connection to the low voltage electricity supply or for battery operation; used indoor and/or outdoor;
– lighting part of multi-function equipment where one of the primary functions of this is illumination;
– independent auxiliaries exclusively for the use with lighting equipment;
– lighting equipment including intentional radiators for wireless communication or control.

Excluded from the scope of this standard are:

– lighting equipment for aircraft and airfields;
– lighting equipment for road vehicles; (except lighting used for the illumination of passenger compartments in public transport)
– lighting equipment for agriculture;
– lighting equipment for boats/vessels;
– photocopiers, slide projectors;
– apparatus for which the requirements of electromagnetic fields are explicitly formulated in other IEC standards.

NOTE The methods described in this standard are not suitable for comparing the fields from different lighting equipment.

This standard does not apply to built-in components for luminaires such as electronic controlgear.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 62209-2:2010, *Human exposure to radio frequency fields from hand-held and body-mounted wireless communication devices – Human models, instrumentation, and procedures – Part 2: Procedure to determine the specific absorption rate (SAR) for wireless communication devices used in close proximity to the human body (frequency range of 30 MHz to 6 GHz)*

IEC 62232:2011, *Determination of RF field strength and SAR in the vicinity of radiocommunication base stations for the purpose of evaluating human exposure*

IEC 62311:2007, *Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz – 300 GHz)*

IEC 62479:2010, *Assessment of the compliance of low-power electronic and electrical equipment with the basic restrictions related to human exposure to electromagnetic fields (10 MHz to 300 GHz)*

CISPR 16-1-1, *Specification for radio disturbance and immunity measuring apparatus and methods. Part 1-1: Radio disturbance and immunity measuring apparatus – Measuring apparatus*

3 Terms, definitions, physical quantities, units and abbreviations

3.1 Terms and definitions

For the purposes of this document the following terms and definitions apply.

3.1.1
ballast
unit inserted between the supply and one or more discharge lamps which by means of inductance, capacitance, or a combination of inductance and capacitance, serves mainly to limit the current of the lamp(s) to the required value

Note 1 to entry: It may also include means for transforming the supply voltage and arrangements that help provide starting voltage and pre-heating current.

3.1.2
basic restriction
basic limitations
restrictions on exposure to time-varying electric, magnetic and electromagnetic fields that are based on established biological effects and including a safety factor

Note 1 to entry: The basic restriction is the maximum level that should not be exceeded under any conditions.

3.1.3
built-in lamp controlgear
lamp controlgear generally designed to be built into a luminaire, a box, an enclosure or the like and not intended to be mounted outside a luminaire, etc. without special precautions

Note 1 to entry: The controlgear compartment in the base of a road lighting column is considered to be an enclosure.

3.1.4
compliance factor
F
factor determined using the Van der Hoofden head test method that represents the measured (weighted and summed) induced internal electric field due to the external electric field in the frequency range 20 kHz to 10 MHz

Note 1 to entry: See Annex D and Annex E.

3.1.5
electronic controlgear
mains-supplied a.c./d.c. to a.c./d.c. invertor including stabilizing elements for starting and operating one or more lamps, generally at high frequency

Note 1 to entry: All kinds of igniters, starters, switches, dimmers (including phase control units e.g. triac, GTO) and sensors are not considered as electronic controlgear.

3.1.6
exposure
exposure occurs whenever and wherever a person is subjected to electric, magnetic or electromagnetic fields or to contact currents other than those originating from physiological processes in the body and other natural phenomena

3.1.7
exposure distance
typical distance between lighting equipment and a person under normal conditions of use

3.1.8
fluorescent lamp
discharge lamp of the low pressure mercury type in which most of the light is emitted by one or several layers of phosphors excited by the ultraviolet radiation from the discharge

Note 1 to entry: These lamps are frequently tubular and, in GB are then usually called fluorescent tubes.

3.1.9
high-intensity discharge lamp
HID lamp
electric discharge lamp in which the light-producing arc is stabilized by wall temperature and the arc has a bulb wall loading in excess of 3 W/cm^2

Note 1 to entry: HID lamps include groups of lamps known as high pressure mercury, metal halide and high pressure sodium lamps.

Note 2 to entry: This note applies to the French language only.

3.1.10
high-pressure lamp
high intensity discharge lamp in which the major portion of the light is produced, directly or indirectly, by radiation from mercury or sodium vapour operating at relatively high levels of partial pressure

3.1.11
independent auxiliary
auxiliaries consisting of one or more separate elements designed so that it can be mounted separately outside a luminaire, with protection according to the marking of the auxiliaries and without any additional enclosure

EXAMPLE: Examples are dimmers, transformers and convertors for incandescent lamps or LED light sources, ballasts for discharge lamps (including fluorescent lamps) and semi-luminaires for compact fluorescent lamps, incandescent lamps or LED light sources

Note 1 to entry: This may consist of a built-in auxiliary housed in a suitable enclosure which provides all the necessary protection according to its markings.

3.1.12
independent lamp controlgear
independent electronic converter
lamp controlgear consisting of one or more separate elements so designed that it can be mounted separately outside a luminaire, with protection according to the marking of the lamp controlgear and without any additional enclosure

Note 1 to entry: This may consist of a built-in lamp controlgear housed in a suitable enclosure that provides all the necessary protection according to its markings.

3.1.13
integral lamp controlgear
lamp controlgear which forms a non-replaceable part of a luminaire and which cannot be tested separately from the luminaire

3.1.14
intentional radiator
any device that is designed to produce electromagnetic fields on purpose in order to provide functions such as wireless communication, control, detection, etc.

3.1.15
lamp controlgear
one or more components between the supply and one or more lamps which may serve to transform the supply voltage, limit the current of the lamp(s) to the required value, provide starting voltage and preheating current, prevent cold starting, correct power factor or reduce radio interference

3.1.16
light emitting diode
LED
solid state device embodying a p-n junction, emitting optical radiation when excited by an electric current

Note 1 to entry: This note applies to the French language only.

3.1.17
lighting equipment
equipment with a primary function of generating and/or regulating and/or distributing optical radiation by electric light source(s)

3.1.18
low-pressure lamp
discharge lamp in which the light is produced by radiation from sodium vapour or mercury

3.1.19
measurement distance
distance between the lighting equipment and the external surface of the measurement test-head

Note 1 to entry: See Annex A.

3.1.20
measurement point
position and location of the measurement test head relative to the lighting equipment

3.1.21
organic light emitting diode
OLED
light emitting semiconductor that has an electroluminescent zone made of organic compounds consisting of a cathode, an anode, and organic electroluminescent layers

Note 1 to entry: This note applies to the French language only.

3.1.22
self-ballasted lamp
unit which can be dismantled without being permanently damaged, provided with a lamp cap and incorporating a light source and additional elements necessary for starting and for stable operating of the light source

3.2 Physical quantities and units

For the purposes of this document the following physical quantities and units given in Table 1 apply.

Table 1 – Physical quantities and units

Quantity	Symbol	Unit	Dimension
Conductivity	σ	Siemens per metre	S/m
Current density	J	Ampere per square metre	A/m^2
Electric field strength	E	Volt per metre	V/m
Frequency	f	Hertz	Hz
Magnetic field strength	H	Ampère per metre	A/m
Magnetic flux density	B	Tesla	T (Wb/m^2, Vs/m^2)
Power	P	Watt	W
Current	I	Ampere	A

3.3 Abbreviations

For the purposes of this document the following abbreviations apply.

a.c.	alternating current
BR	basic restriction
CISPR	Comité International Spécial des Perturbations Radioélectriques
d.c.	direct current
DUT	device under test
EIRP	equivalent isotropically radiated power
EMF	electromagnetic field
EMI	electromagnetic interference
ERP	effective radiated power
GTO	gate turn off
HID	high intensity discharge
ICNIRP	International Commission on Non-Ionizing Radiation Protection
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IR	Infrared
LED	light emitting diode
LLA	large loop antenna
NWA	network analyser
OLED	organic light emitting diode
PRF	pulse repetition frequency
RF	radio frequency
r.m.s.	root mean square
SAR	specific absorption rate
UV	ultraviolet
WBA	whole-body average

4 Limits

4.1 General

The basic restrictions or reference levels for the general public of either IEEE C95.1-2005 or ICNIRP 1998 and ICNIRP 2010 are used, see Annex C.

Lighting equipment shall comply with the Van der Hoofden test limit (4.2.3), unless it is inherently compliant (4.2.2). If equipped with intentional radiators, it shall also pass the assessment procedure for intentional radiators (4.3). An overview of the routes to demonstrate compliance against these limits is given in Figure1.

4.2 Unintentional radiating part of lighting equipment

4.2.1 General

This subclause 4.2 applies for lighting equipment, excluding the intentional radiating part (as far as applicable).

4.2.2 Lighting equipment deemed to comply with the Van der Hoofden test without testing

Lighting equipment is deemed to comply with the requirements of this standard without testing if it fulfils one of the following inherent-compliance conditions:

1) it contains no electronic controlgear;
2) it is incandescent-lamp technology, including halogen;
3) it is a LED-light-source technology;
4) it is an OLED light-source technology;
5) it is high-pressure discharge lamp technologies;
6) it is based on low-pressure discharge lamp technologies with an exposure distance larger than or equal to 50 cm (according to Table A.1);
7) it is an independent auxiliary.

The background and rationale for these conditions is given in the informative Annex H.

Lighting equipment that does not fulfil any of these conditions is subject to the requirements given in 4.2.3.

4.2.3 Application of limits

Lighting equipment, as described in the scope, and which does not fulfil one of the inherent compliance conditions mentioned in 4.2.2, complies with this standard if the compliance factor F (see 3.1.4) is less than or equal to 1.

4.3 Intentional radiating part of lighting equipment

If one or more intentional radiators are part of the lighting equipment, then for compliance with this standard, one of the methods given in Clause 7 shall be applied and the conditions satisfied. See also Annex I for details.

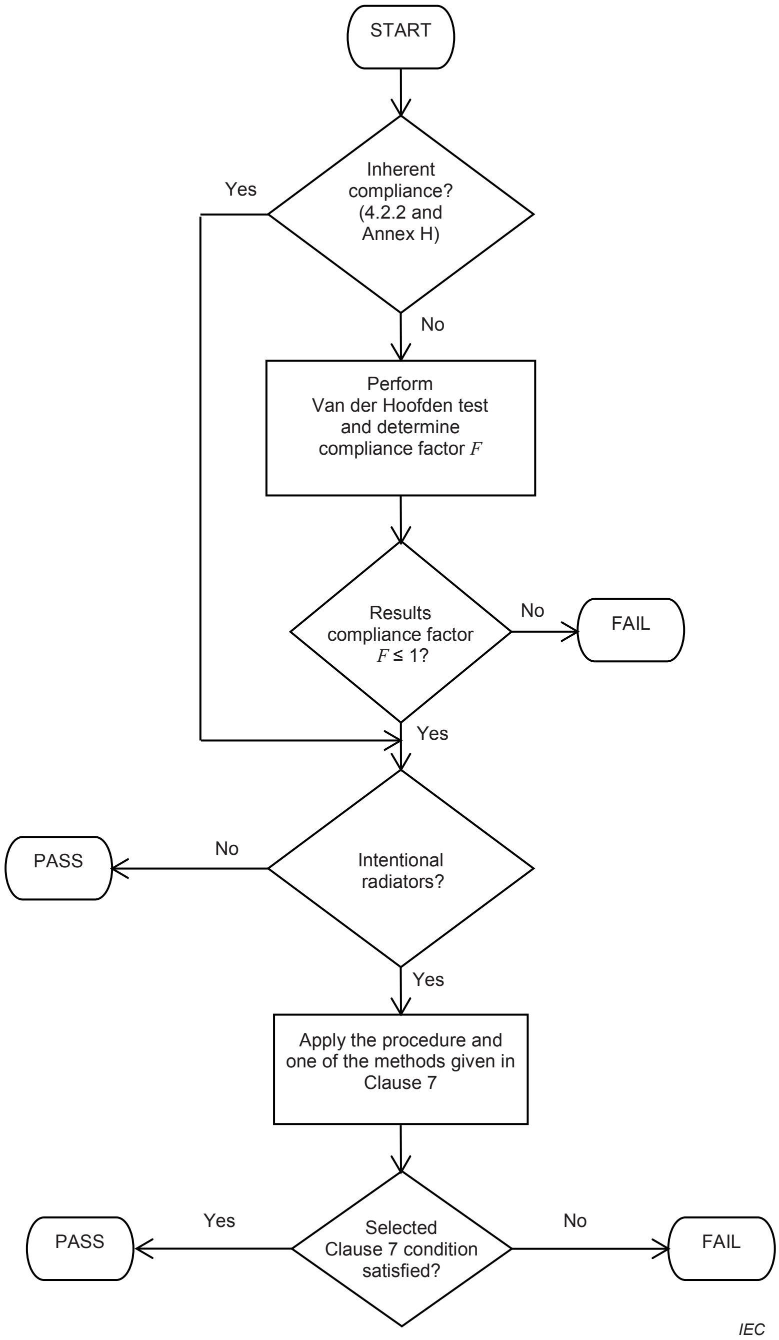


Figure 1 – Compliance routes and pass/fail criteria for lighting equipment

5 General requirements Van der Hoofden test

5.1 Measurand

The induced internal electric field level is determined by measuring the capacitive current $I_{\text{cap}}(f_n)$ into a standardised test head (see Figure 4 and Annex E for details). The capacitive current is measured as a voltage $V(f_n)$ by a spectrum analyser or receiver through a coupling network (see Figure 3), the voltage being a function of the frequency. This Clause 5 gives details on the test head, the measuring instrumentation and the measuring conditions.

5.2 Supply voltage and frequency

For a.c.-operated equipment, measurements shall be carried out at mains a.c.-voltage within ±2 % of the maximum rated supply voltage.

Equipment which can be operated from different a.c.-supply voltages and a.c.-supply frequencies shall be measured only at one a.c.-supply voltage within ±2 % of the maximum rated supply voltage and at one a.c.-supply frequency (50 Hz or 60 Hz).

Equipment which can be operated from both (multiple) a.c.- and/or d.c. supplies shall be measured only at one d.c.-supply voltage within ±2 % of the maximum rated d.c.-supply voltage.

5.3 Measurement frequency range

The measurement frequency range considered is from 20 kHz to 10 MHz (see Annex E).

5.4 Ambient temperature

Measurements shall be carried out in the ambient temperature range 15 °C to 25 °C.

5.5 Measurement equipment requirements

An electromagnetic interference (EMI) test receiver or spectrum analyser according to CISPR 16-1-1 is required, with the settings given in Table 2:

Table 2 – Receiver or spectrum analyser settings

Frequency range	B_6	Measurement time	f_{step}	Detector
20 kHz to 150 kHz	200 Hz	100 ms	220 Hz	Peak
150 kHz to 10 MHz	9 kHz	20 ms	10 kHz	Peak
B_6 is the 6 dB bandwidth as specified in CISPR 16-1-1.				

A Van der Hoofden test head, as depicted in Figure 2, consists of a conducting sphere with an outside diameter of D_{head} = 210 mm ± 5 mm mounted on an insulated (e.g. wood, plastic) support and connected via an ordinary wire to a protection network.

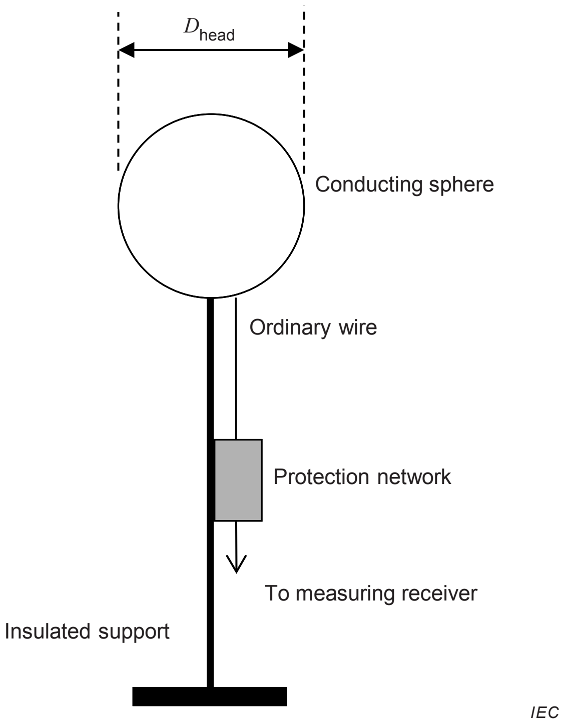
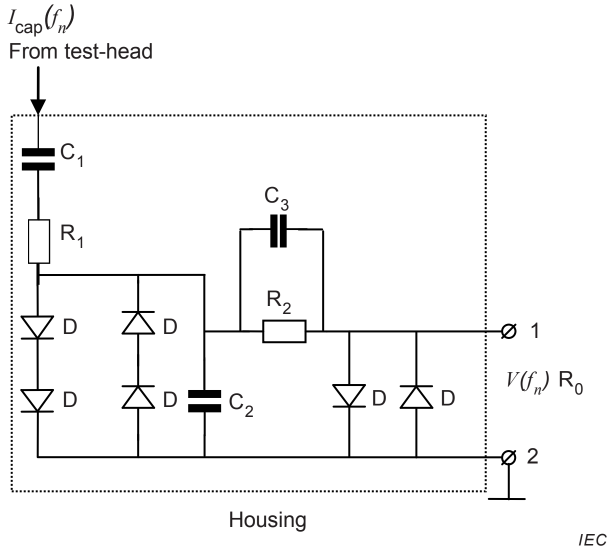


Figure 2 – The Van der Hoofden test head

An example of the protection circuit can be found in Figure 3.



Example
C_1 = 470 pF
C_2 = 10 nF
C_3 = optional capacitor (~56 pF)
to fulfill the transfer function
requirements of Annex F
R_1 = 470 Ω
R_2 = 150 Ω
D = Schottky diode
R_0 = 50 Ω input of EMI receiver
Terminals 1 and 2 are to be connected to an EMI receiver or spectrum analyzer via coaxial cable

Figure 3 – Example of a protection circuit

The transfer function of the protection network is given by Equation (1)

$$g(f_n) = \frac{V(f_n)}{I_{cap}(f_n)} = \frac{R_0}{\sqrt{1 + \left[(R_0 + R_2) \cdot 2 \cdot \pi \cdot f_n \cdot C_2\right]^2}} \qquad (1)$$

The transfer function of the protection network shall not deviate more than ±1 dB from the calculated characteristic (see Annex F for calculation). The calibration of the protection network shall be done according to the procedure described in detail in Annex F.

An overview of the measurement set-up is given in 6.4.

5.6 Measurement instrumentation uncertainty

A basic measurement instrumentation uncertainty U_{basic} is estimated to be 30 %. The actual instrumentation uncertainty of the measurement method applied within a laboratory (U_{lab}) shall be calculated. The actual uncertainty shall be used for compliance evaluation of the result (see 5.8). An example for the calculation of U_{lab} can be found in Annex G.

NOTE Guidance to assess uncertainty can be found in IEC 61786:1998 [5].

5.7 Test report

The test report shall include at least the following items:

– identification of the lighting equipment;
– specification of the measuring equipment;
– operating mode, measurement point(s) and distance(s)

– rated voltage and frequency;
– measurement result;
– applied limit set.

5.8 Evaluation of results

Compliance or non-compliance with the limit shall be determined in the following manner.

If the uncertainty calculated with the instrumentation actually used for the test (U_{lab}) is less than or equal to the uncertainty given in 5.6 (U_{basic}) then:

– compliance is deemed if the measurement result does not exceed the applicable limit;
– non-compliance is deemed to occur if the measurement result exceeds the applicable limit.

If the uncertainty calculated with the instrumentation used for the test (U_{lab}) is higher than the uncertainty given in 5.6 (U_{basic}) then:

– compliance is deemed to occur if the measurement result, increased by ($U_{lab} - U_{basic}$), does not exceed the applicable limit.
– non-compliance is deemed to occur if the measurement result, increased by ($U_{lab} - U_{basic}$), exceeds the applicable limit.

6 Measurement procedure for the Van der Hoofden test

6.1 General

The assessment method is based on basic restrictions given in both ICNIRP 1998 and ICNIRP 2010, or in IEEE C95.1-2005. The measurement procedure used simulates the induced internal electric field in a person near lighting equipment. The measurements are carried out under the conditions specified in this Clause 6.

6.2 Operating conditions

6.2.1 Operating conditions for lighting equipment

Measurements on the lighting equipment shall be carried out in operating conditions as specified by the manufacturer.

In the case of lighting equipment where it is possible to interchange between lamps of different rated wattage, it is only necessary to measure the lighting equipment in combination with the lamp that has the highest nominal lamp voltage.

Prior to measurement, the lamp(s) shall be operated until stabilisation has been reached. Unless otherwise stated by the manufacturer, the following stabilisation times shall be observed:

– 15 min for low-pressure discharge lamps;
– 30 min for other discharge lamps.

All measurements shall be done with 100 h aged lamps.

6.2.2 Operating conditions for specific lighting equipment

Multiple lamp lighting equipment: When the lighting equipment incorporates more than one lamp, all lamps shall be operated simultaneously.

Self-contained emergency lighting equipment: If the appliance can be connected and be operated from the mains it shall be tested in this mode of operation. No tests are required in the battery-operating mode.

Lighting equipment capable of light regulation shall be measured at both the minimum and maximum limit of light regulation.

6.2.3 Operating conditions for lighting equipment with intentional radiators

The intentional radiating part of the DUT shall be disabled during the Van der Hoofden head test unless this action renders operation of the DUT impossible.

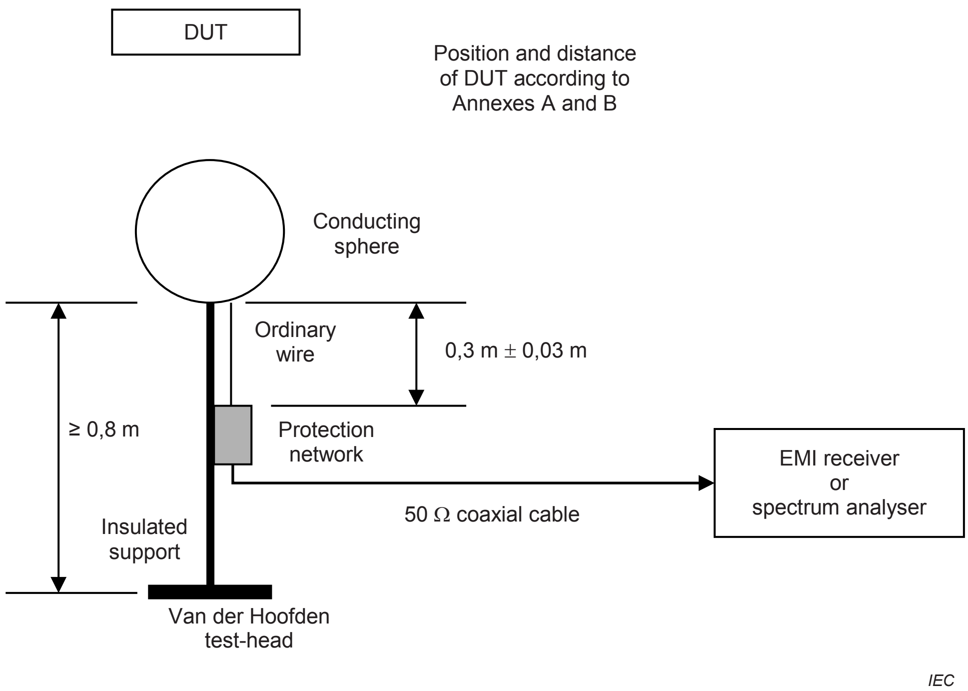
6.3 Measurement distance

Lighting equipment is evaluated in accordance with the measurement distance given in Table A.1 of Annex A unless otherwise specified by the manufacturer where a limitation of use is specified in the installation instructions. The external surface of the test head is taken as the reference point when determining the measurement distance. See Figures B.1 to B.10 in Annex B. Tolerances of the measurement distances are ±5 %.

6.4 Measurement set-up

6.4.1 General

The measurement set-up is given in Figure 4.



Key

DUT device under test.

Figure 4 – Measurement set-up

If the lighting equipment is provided with an earthing terminal, the lighting equipment shall be connected by means of an earth conductor contained in the power cable to the lighting equipment.

The EMI receiver or spectrum analyser shall be powered by mains including protective earth.

During the tests no conductive plane or object or human being should be closer to the lighting equipment than 0,8 m.

The height of the insulated support is minimum 0,8 m. The conducting sphere is connected to the protection network via an ordinary wire of length 30 cm ± 3 cm. The protection network is then connected to the EMI receiver, or spectrum analyser, by a 50 Ω coaxial cable having a maximum cable loss of 0,2 dB and a d.c. resistance of ≤10 Ω.

6.4.2 Measurement set-up for specific lighting equipment

6.4.2.1 Self-ballasted lamps

These lamps shall be inserted directly into a lamp holder, which is mounted on a piece of insulating material. The measurement test head is positioned at the measurement distance as specified in Table A.1 from the end of the lamp.

6.4.2.2 Independent electronic controlgear

Independent electronic controlgear shall be mounted on a piece of insulating material together with a suitable lamp of the maximum permitted power. The load cable(s) between the controlgear and the lighting equipment shall be 0,8 m with a relative tolerance of 20 % unless otherwise specified by the manufacturer. The configuration of controlgear, lighting equipment and cable(s) shall be measured in accordance with Figure B.9.

6.5 Location of measurement test head

The measurement locations of the test head shall be selected in accordance with the following criteria.

Measurements shall only be performed in a direction consistent with that of the likely exposure of the general public during normal use.

The general principles for the location of the conducting sphere of the test head with respect to the device under test (DUT) is outlined in more detail in the Figures B.1 to B.3 of Annex B.

In the case of lighting equipment incorporating double capped fluorescent lamps greater than 30 cm, the test head is positioned as shown in Figure B.2. The measurement procedure is repeated for both ends of the lamp, and in the case of multiple-lamp lighting equipment, each lamp is measured in-turn.

In the case of lighting equipment for other lamps, the test head is positioned at the appropriate measurement distance as specified in Table A.1, central to the point of intended illumination.

For those lighting equipment where a central point of illumination cannot be determined, or where the direction of illumination is not in the direction of the general public during normal use, for example an up light, a measurement point is selected at the appropriate test distance from the lighting equipment around its perimeter. More than one measurement point may be selected to confirm the performance of the lighting equipment.

Figures B.4 to B.10 give examples of the location of the measurement point(s) for typical lighting equipment.

6.6 Calculation of the results

The measurement results are calculated in accordance with Annex E.

7 Assessment procedure intentional radiators

7.1 General

Figure 5 shows the options for the compliance demonstration of the intentional radiating part of the lighting equipment. This Clause 7 gives further guidance on these different options.

7.2 Low-power exclusion method

7.2.1 General

The first option for compliance demonstration of the intentional radiating part of lighting equipment is based on determination of the total average radiated power of the intentional radiator. This so called low-power exclusion approach is specified in IEC 62479. In this approach, low-power exclusion levels are specified. If the actual total averaged (6 min) power $P_{\mathrm{int,rad}}$ at the input of an intentional transmitter is below the exclusion level P_{max}, then the product complies by design without further testing if the following relation is fulfilled:

$$P_{\text{int,rad}} < P_{\text{max}} \quad (2)$$

See Clause I.4 for further information on the low-power exclusion approach.

7.2.2 Determination of the total radiated power

Generally, the total radiated power $P_{\text{int,rad}}$ can be determined from design specifications of the intentional radiators that are applied. When determining the value of $P_{\text{int,rad}}$ one has to take care of the way how the power is specified. Also, in case of pulsed power, the duty cycle of the transmitted signal has to be incorporated, because the 6 min average has to be determined. Annex I gives further guidance on how to determine $P_{\text{int,rad}}$.

7.2.3 Determination of the low-power exclusion level

The basic EMF standard IEC 62479 gives low-power exclusion levels P_{max} based on the various basic restrictions that apply and the various categories of exposed humans (general public, occupational). See Table A.1 of IEC 62479:2010. For instance for ICNIRP 1998, general public exposure, the worst case low-power exclusion level is 20 mW for head and trunk. However, in practice much larger exclusion levels P_{max} are obtained because of the minimum exposure distance of certain lighting equipment, and due to properties of the applied antennas. Subclause I.4.3 gives more guidance on determination of the low-power exclusion levels P_{max}.

7.2.4 Summation of multiple transmitters

In case of lighting equipment with multiple intentional radiators, the contributions from the individual intentional transmitters are to be added. The way of summation depends on whether RF-signals of the individual transmitters are correlated or not. Clause I.5 gives more guidance on the summation method and its compliance criterion.

7.3 Application of the EMF product standard for body worn-equipment

In case, the low-power exclusion level criterion is not met (7.2), and if the exposure distance between the intentional radiating part of the lighting equipment and the exposed person is less or equal than 0,05 m, then the specific EMF product standard IEC 62209-2 for body-worn equipment shall be applied for compliance demonstration.

7.4 Application of the EMF product standard for base stations

In case, the low-power exclusion level criterion is not met (7.2), and if the intentional radiating part of the lighting equipment is a base station, then the specific EMF product standard IEC 62232 for base-station shall be applied for compliance demonstration using the applicable assessment distance and limits.

7.5 Application of another EMF standard

In case, the low-power exclusion level criterion is not met (7.2), and if the intentional radiating part cannot be considered as body-worn equipment (7.3) or as a base station (7.4), then possibly another EMF product standard may be applied or alternatively the generic EMF standard IEC 62311 shall be applied for compliance demonstration using the applicable assessment distance and limits.

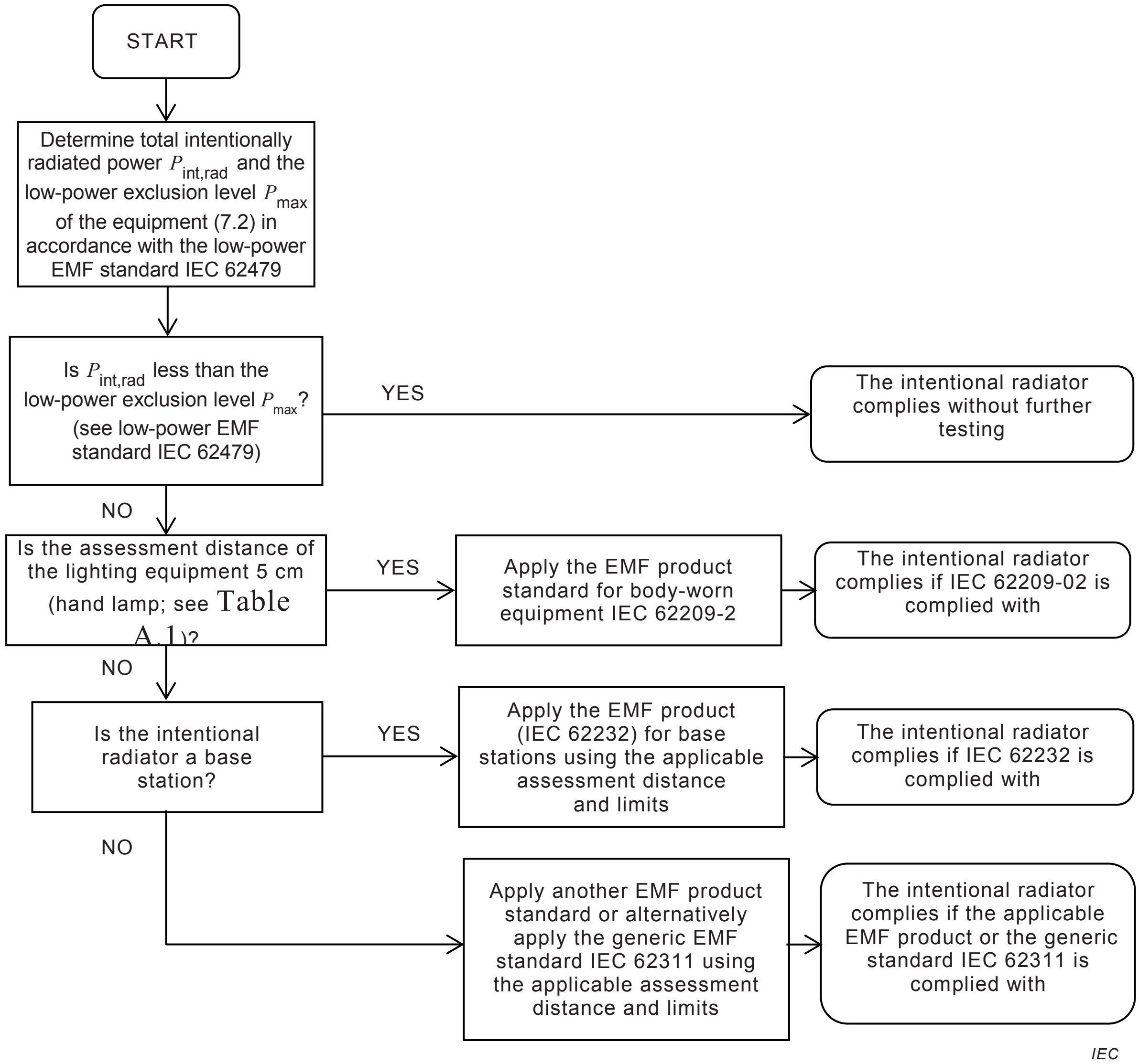


Figure 5 – Compliance demonstration procedure for the intentional-transmitter part of the lighting equipment

Annex A
(normative)

Measurement distances

The measurement distances in Table A.1 have been defined, based upon the expected location of the general public during normal operation.

Table A.1 – Lighting equipment and measurement distances

Type of lighting equipment [c]	Measurement distance cm
Hand lamps [a]	5[a]
Table lighting equipment	30
Wall lighting equipment	50
Up lighter	50
Suspended lighting equipment	50
Ceiling and/or recessed lighting equipment for fluorescent lamps with an input power[b] $\leq$ 180 W	50
Ceiling and/or recessed lighting equipment for fluorescent lamps with an input power[b] $>$ 180 W	70
Ceiling and/or recessed lighting equipment for discharge lamps with an input power[b] $\leq$ 180 W	70
Ceiling and/or recessed lighting equipment for discharge lamps with an input power[b] $>$ 180 W	100
Portable lighting equipment	50
Flood lights	200
Lighting equipment for road and street lighting	200
Lighting chains	50
Lighting equipment for swimming-pools and similar applications	50
Lighting equipment for stage lighting, television and film studios (outdoor and indoor)	100
Lighting equipment for use in clinical areas of hospitals and health care buildings	50
Ground recessed lighting equipment	50
Aquarium lighting equipment	50
Plug- in night lights	50
Self-ballasted lamps	30
UV and IR radiation equipment	50
Transport lighting (installed in the passenger compartment of buses and trains)	50
Other lighting equipment not mentioned in this table	50

[a] Measurement distance should be 30 cm and the measured value should be calculated to a distance of 5 cm (equation: $1/r^3$).

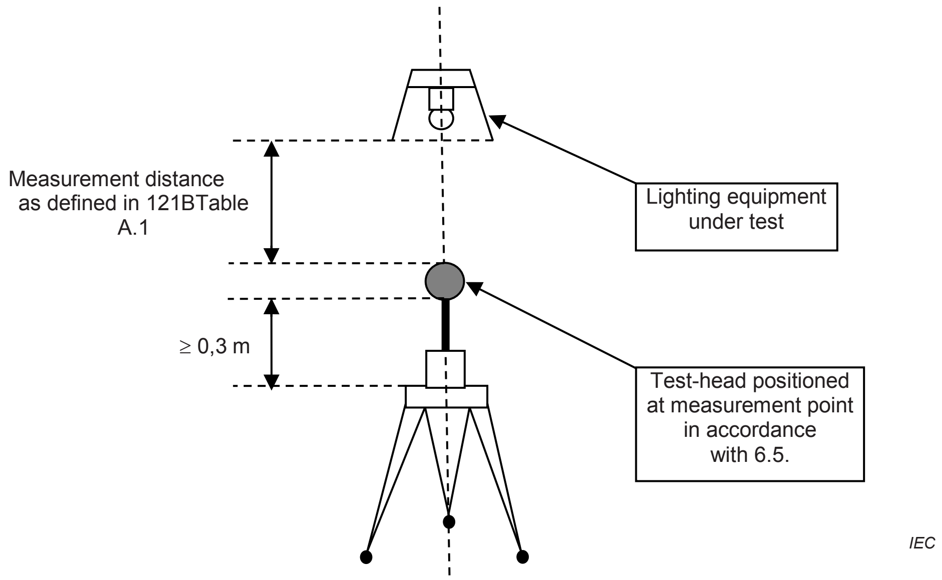
[b] Total nominal power of the lighting equipment.

[c] If LE (lighting equipment) falls into more than one category, then the category with the shortest measurement distance applies.

Annex B
(informative)

Location of measurement test head

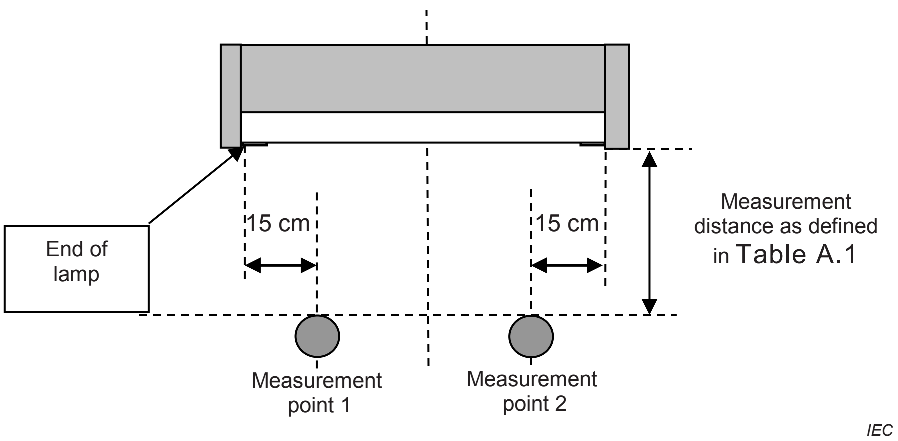
The Figures B.1 through B.10 in this annex contain arrangements (position, orientations) of the Van der Hoofden test head with respect to the lighting equipment under test. See also 6.4 and 6.5 for detailed specifications of the measurement arrangements.



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with double capped fluorescent lamp(s).

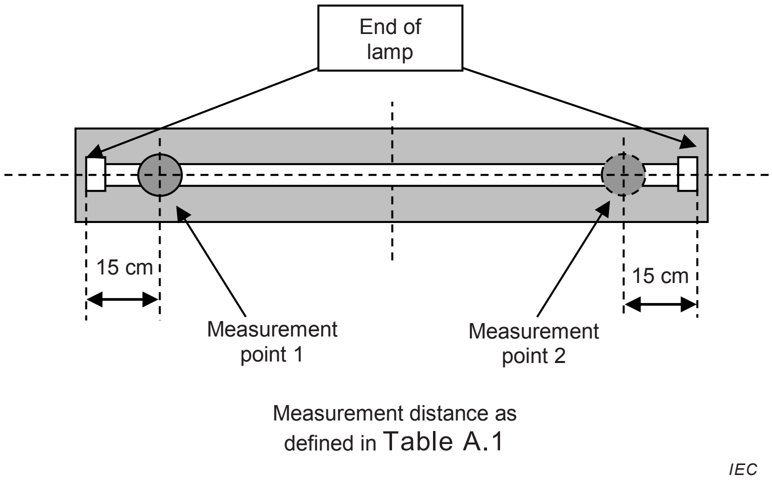
Figure B.1 – Location of measurement point in the transverse direction of lighting equipment – side view



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with double capped fluorescent lamp(s)

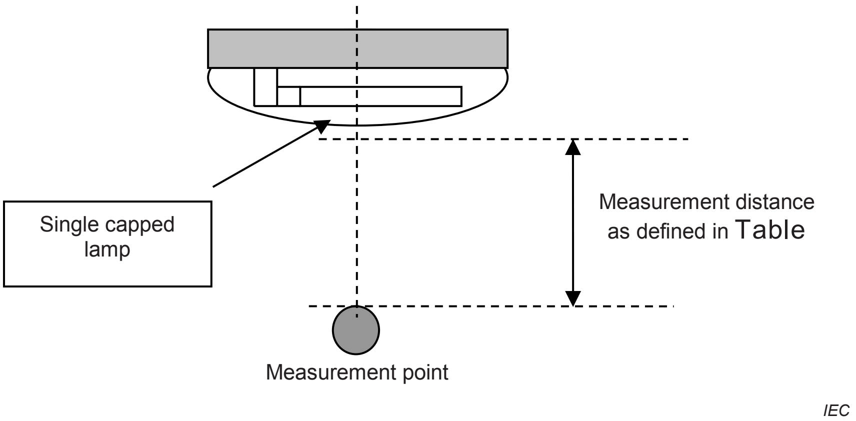
Figure B.2 – Location of measurement points in the longitude direction of lighting equipment – side view



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with double capped fluorescent lamp(s)

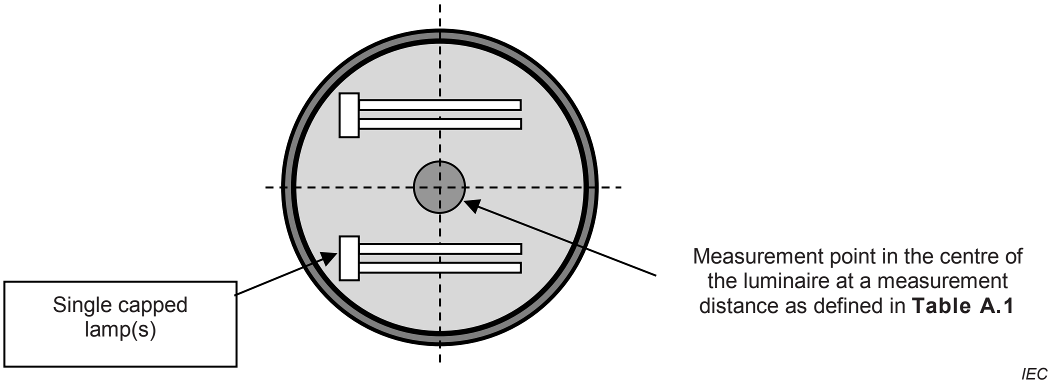
Figure B.3 – Location of measurement points in the longitude direction of lighting equipment; in the direction of illumination



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with single capped fluorescent lamp(s)

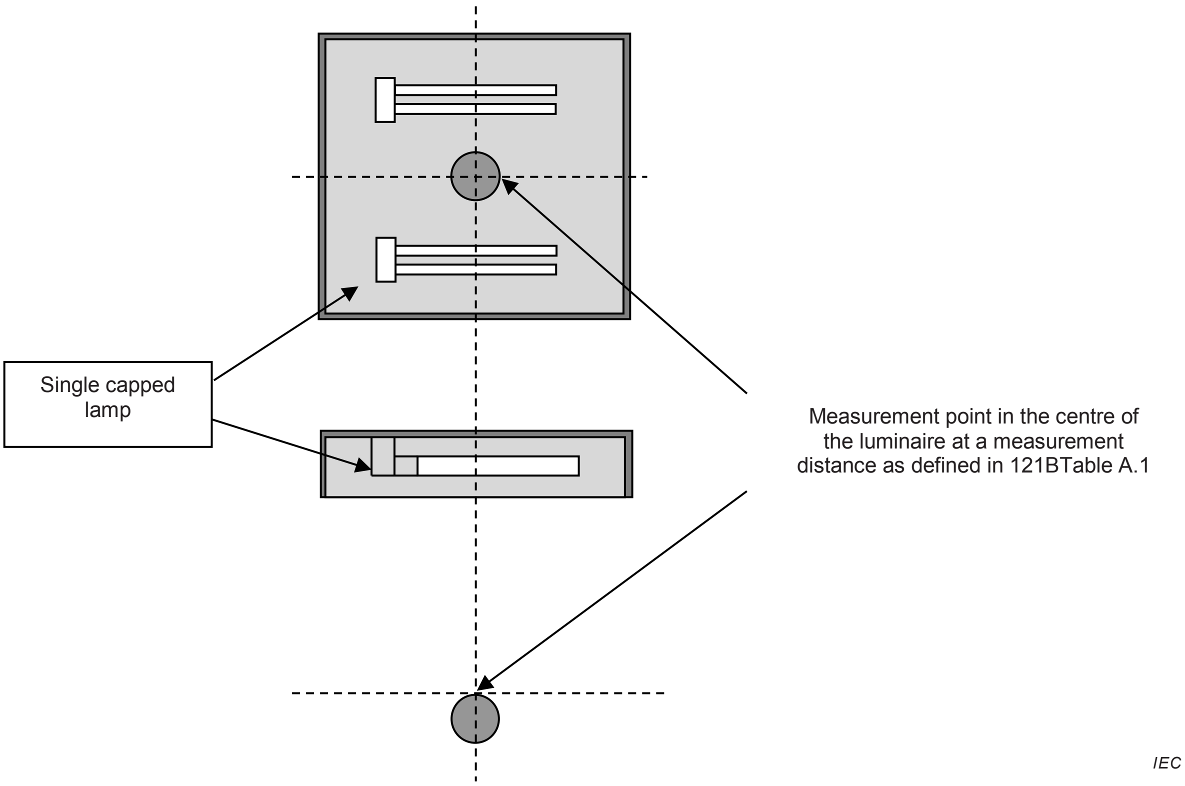
Figure B.4 – Location of measurement point for lighting equipment with rotationally symmetrical dimensions



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with single capped fluorescent lamp(s) or other single capped lamp(s)

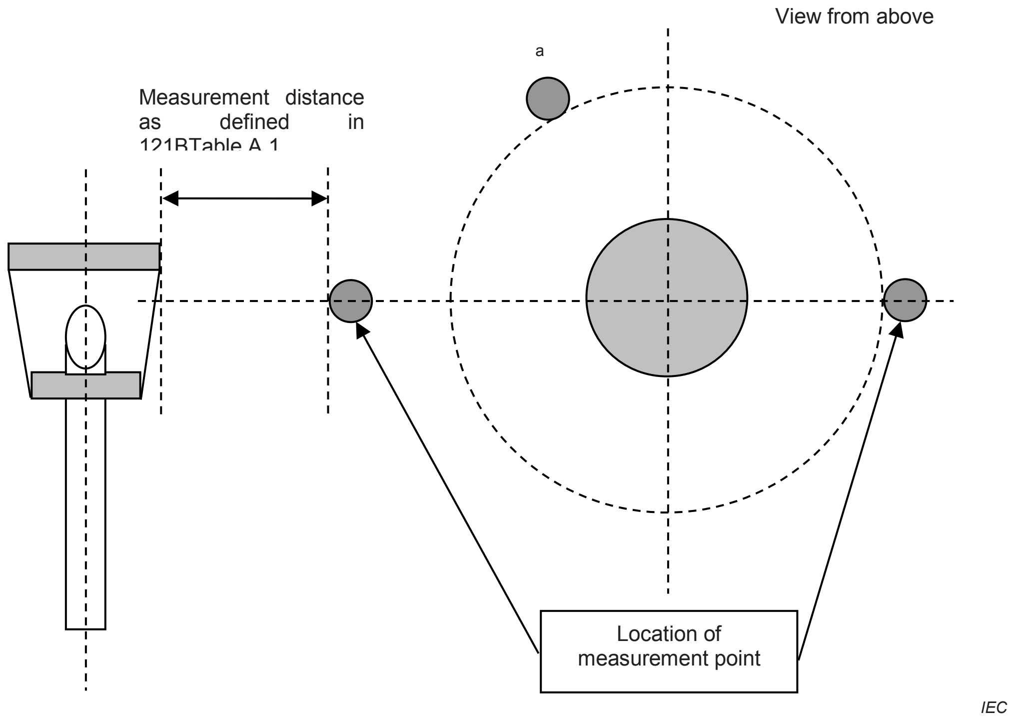
Figure B.5 – Location of measurement point for lighting equipment with rotationally symmetrical dimensions; in the direction of illumination



This applies to recessed, surface or pole mounted lighting equipment.

NOTE Examples include luminaires with single or capped lamp(s)

Figure B.6 – Location of measurement point for lighting equipment with the same dimensions in the x- and y- axis



[a] Additional measurement points may be applied around the perimeter of the lighting equipment.

Figure B.7 – Location of measurement point(s) for lighting equipment with single capped lamp (360° illumination)

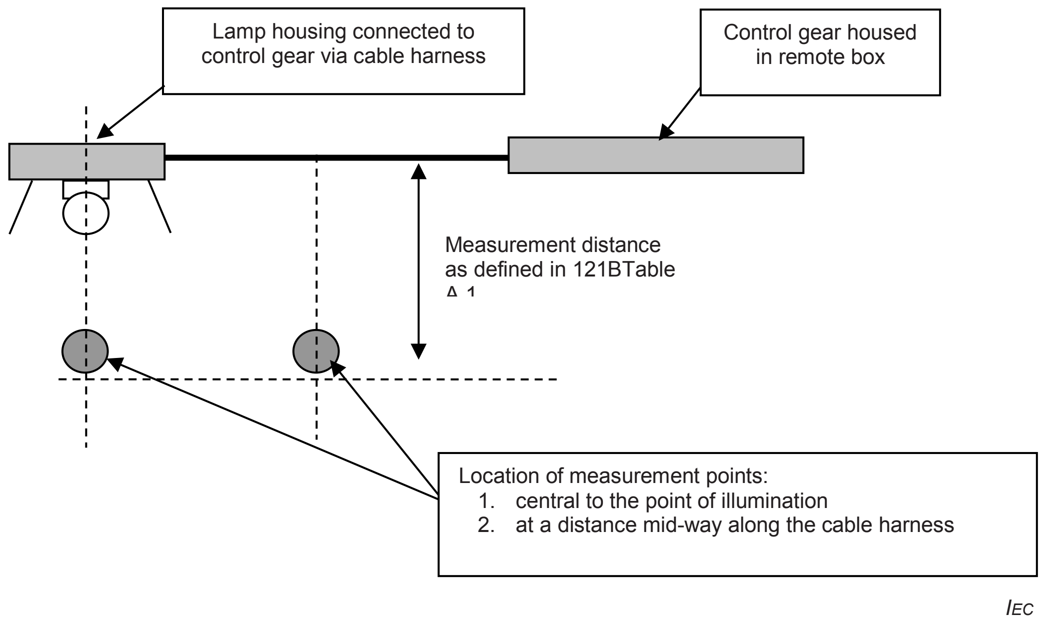
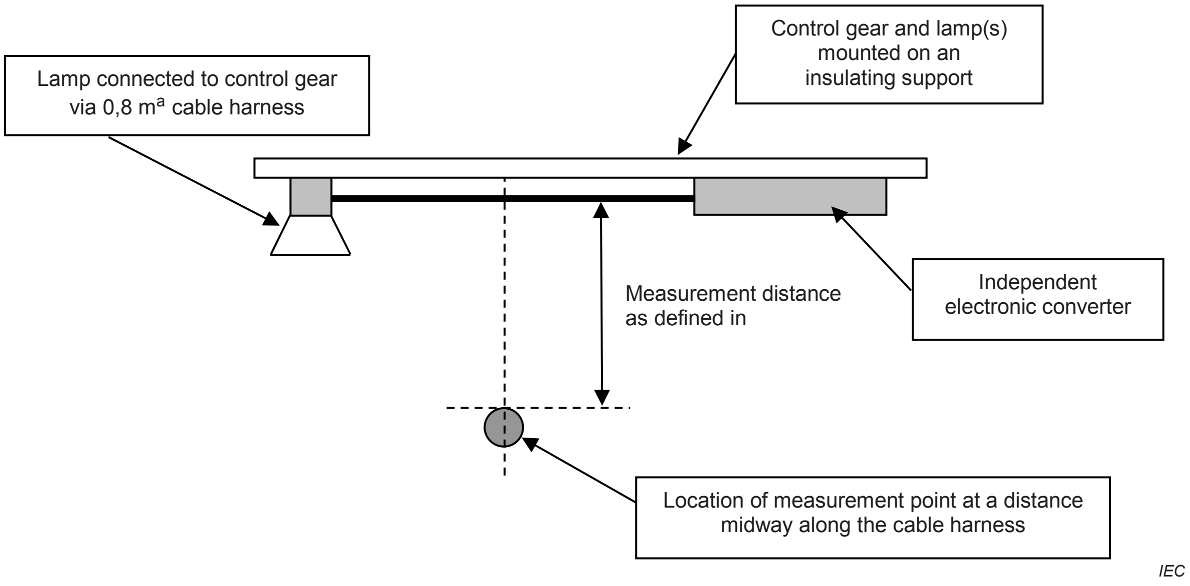
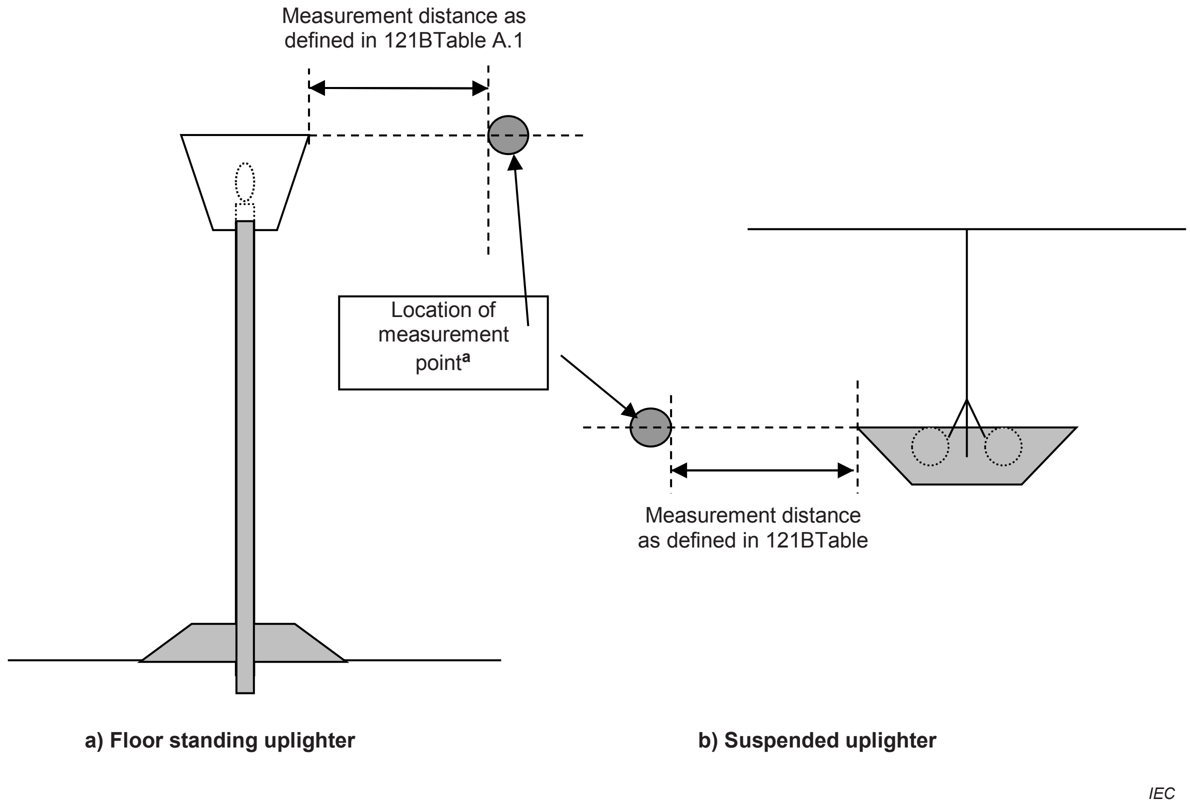


Figure B.8 – Location of measurement points for lighting equipment with a remote controlgear



[a] Length of cable 0,8 m unless defined otherwise in manufacturer's installation instructions.

Figure B.9 – Location of measurement point for an independent electronic converter



[a] In the case of linear fluorescent lamps, the test-head is located perpendicular to the lamp(s) 15 cm from the end of the lamp(s), as depicted in Figure B.2.

Figure B.10 – Location of measurement point(s) for an uplighter (floor standing/suspended)

Annex C
(informative)

Exposure limits

C.1 General

The exposure limits given in this informative annex (see [1], [2], [3] and [4]) are for information only, do not comprise an exhaustive list and are valid only in certain regions of the world. It is the responsibility of users of this standard to ensure that they use the current version of the limit values specified by the applicable national authorities.

C.2 ICNIRP

C.2.1 ICNIRP 1998

Table C.1 provides the basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies between 100 kHz and 10 GHz (see [1]):

Table C.1 – Basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies between 100 kHz and 10 GHz

Frequency range	Average SAR (whole body) W/kg	Localised SAR (head and trunk) W/kg	Localised SAR (limbs) W/kg
100 kHz to 10 GHz	0,08	2	4

C.2.2 ICNIRP 2010

Table C.2 provides the basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies up to 10 MHz (see [2]):

Table C.2 – Basic restrictions for general public exposure to time varying electric and magnetic fields for frequencies up to 10 MHz

Exposure characteristic	Frequency range	Internal electric field V/m
CNS tissue of the head	1 Hz to 10 Hz	$0,1/f$
	10 Hz to 25 Hz	0,01
	25 Hz to 1 000Hz	$4 \times 10^{-4} f$
	1 000 Hz to 3 kHz	0,4
	3 kHz to 10 MHz	$1,35 \times 10^{-4} f$
All tissues of the head and body	1 Hz to 3 kHz	0,4
	3 kHz to 10 MHz	$1,35 \times 10^{-4} f$
f is the frequency in Hz. All values are r.m.s.		

C.3 IEEE

Table C.3 provides the IEEE basic restrictions (BR) for the general public between 0 Hz and 3 kHz (see [4]) and Table C.4 provides the IEEE Basic Restrictions (BR) between 100 kHz and 3 GHz for the general public (see [3]).

Table C.3 – IEEE basic restrictions (BR) for the general public

		Action level [a]			Persons in controlled environments		
Exposed tissue	F_e Hz	E_0	r.m.s.	V/m	E_0	r.m.s.	V/m
Brain	20	$5{,}89 \times 10^{-3}$			$1{,}77 \times 10^{-2}$		
Heart	167	0,943			0,943		
Extremities	3 350	2,10			2,10		
Other tissues	3 350	0,701			2,10		

E_0 is the rheobase in situ field. f_e is the frequency parameter.

[a] Within this frequency range the term “action level” is equivalent to the term “general public” in IEEE Std C95.6-2002.

NOTE Entries in Table C.3 and elsewhere in this standard are sometimes given to three significant digits. This degree of precision is provided so that the reader can follow the various derivations and relationships presented in this standard, and does not imply that the numerical quantities are known to that precision.

Table C.4 – IEEE basic restrictions (BR) between 100 kHz and 3 GHz for the general public

		Action level[a] SAR[b] W/kg	Persons in controlled environments SAR[c] W/kg
Whole-body exposure	Whole-Body Average (WBA)	0,08	0,4
Localized exposure	Localized (peak spatial-average)	2[c]	10[c]
Localized exposure	Extremities[d] and pinnae	4[c]	20[c]

[a] BR for the general public when an RF safety program is unavailable.

[b] SAR is averaged over the appropriate averaging times.

[c] Averaged over any 10 g of tissue (defined as a tissue volume in the shape of a cube –the volume of the cube is approximately 10 cm^3).

[d] The extremities are the arms and legs distal from the elbows and knees, respectively.

Annex D
(informative)

Rationale measurement and assessment method

D.1 General

The ICNIRP and IEEE based exposure compliance measurement and assessment method, given in this annex (see Figure D.1), consists of an evaluation of the internal electric field (see Clause D.2) and the thermal effects (see Clause D.3). The assessment in this annex is based on the case that the equipment does not include intentional radiators and that the unintended EM-emissions of the equipment complies with the electromagnetic compatibility (EMC) requirements that apply for lighting equipment. As a typical example, the International IEC Standard for EM-disturbances of lighting equipment (CISPR 15) has been applied in this annex. However, a similar assessment may be performed using other EMC emission standards. Note that although calculations given in this annex are based on CISPR 15 limits, even exceeding these limits by significant margin is unlikely to cause an EMF safety risk.

In case the lighting equipment includes intentional radiators, then an additional compliance criterion applies. See Annex I and Clause 7 for details.

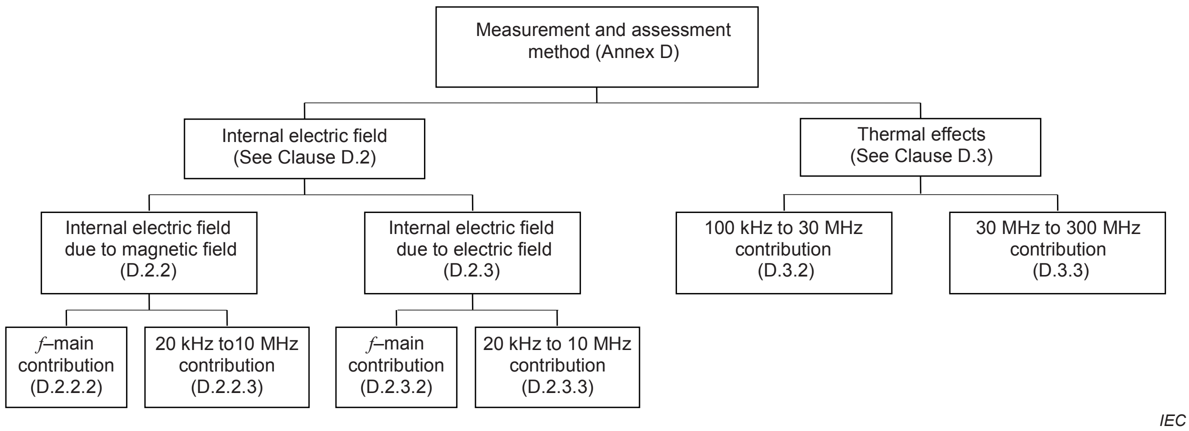


Figure D.1 – Overview measurement and assessment method

D.2 Induced internal electric field

D.2.1 General

Based on the basic restrictions, the induced internal electric field in a (dummy) person shall meet the requirement of Equation (D.1):

$$\sum_{f_i = 1\,\text{Hz}}^{10\,\text{MHz}} \frac{E(f_i,d)}{E_{\text{Lim}}(f_i)} \leq 1 \qquad \text{(D.1)}$$

where

$E(f_i,d)$ is the induced internal electric field at frequency f_i and at a measurement distance d according to Annex A;

$E_{\text{Lim}}(f_i)$ is the internal electric field density basic restriction at frequency f_i of Table C.1.

The induced electric field in the (dummy) person can be caused by:

- eddy currents in the (dummy) person due to the magnetic field of lighting equipment under test, as described in D.2.2.

- capacitive currents from lighting equipment under test to the (dummy) person due to the electric field, as described in D.2.3.

So Equation (D.1) can be rewritten as:

$$\sum_{f_i=1\text{Hz}}^{10\text{MHz}} \frac{E_{\text{eddy}}(f_i,d)}{E_{\text{Lim}}(f_i)} + \sum_{f_i=1\text{Hz}}^{10\text{MHz}} \frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)} \leq 1 \qquad \text{(D.2)}$$

where

$E_{\text{eddy}}(f_i,d)$ is the induced internal electric field due to the external magnetic field at frequency f_i and at a distance d according to Annex A;

$E_{\text{cap}}(f_i,d)$ is the induced internal electric field due to the external electric field at frequency f_i and at a distance d according to Annex A

The frequencies for the power converters in the lighting equipment are higher than 20 kHz in order to avoid audible noise and infrared interference. With this knowledge Equation (D.2) can be rewritten as:

$$\sum_{f_i=1\text{Hz}}^{20\text{kHz}} \frac{E_{\text{eddy}}(f_i,d)}{E_{\text{Lim}}(f_i)} + \sum_{f_i=20\text{kHz}}^{10\text{MHz}} \frac{E_{\text{eddy}}(f_i,d)}{E_{\text{Lim}}(f_i)} + \sum_{f_i=1\text{Hz}}^{20\text{kHz}} \frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)} + \sum_{f_i=20\text{kHz}}^{10\text{MHz}} \frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)} \leq 1 \qquad \text{(D.3)}$$

The mains frequency of 50 Hz or 60 Hz is the only relevant frequency component in the frequency area of 1 Hz to 20 kHz. Therefore Equation (D.3) can be rewritten as:

$$\underbrace{\frac{E_{\text{eddy}}(f_{\text{mains}},d)}{E_{\text{Lim}}(f_{\text{mains}})}}_{\text{(D.4.a)}} + \underbrace{\sum_{f_i=20\text{kHz}}^{10\text{MHz}} \frac{E_{\text{eddy}}(f_i,d)}{E_{\text{Lim}}(f_i)}}_{\text{(D.4.b)}} + \underbrace{\frac{E_{\text{cap}}(f_{\text{mains}},d)}{E_{\text{Lim}}(f_{\text{mains}})}}_{\text{(D.4.c)}} + \underbrace{\sum_{f_i=20\text{kHz}}^{10\text{MHz}} \frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)}}_{\text{(D.4.d)}} \leq 1 \qquad \text{(D.4)}$$

The following subclauses D.2.2 and D.2.3 indicate how much each subpart of Equation (D.4) contributes.

D.2.2 Induced electric field due to the magnetic field; $E_{eddy}(f_i,d_{loop})$

D.2.2.1 General

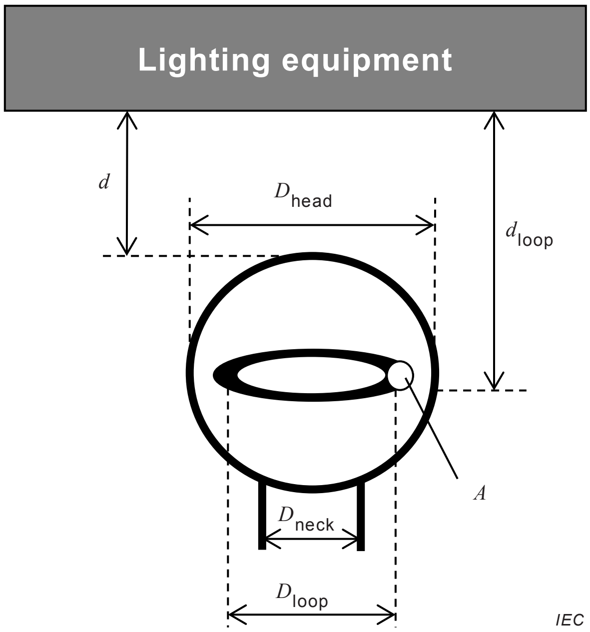


Figure D.2 – Distances of the head, loop and measurement set-up

The induced voltage in a loop in the head (see Figure D.2) due to the magnetic field can be calculated by Equation (D.5)

$$V_{ind}(f_i,d_{loop}) = \frac{\pi}{4} \cdot D_{loop}^2 \cdot 2 \cdot \pi \cdot f_i \cdot B(f_i,d_{loop}) \tag{D.5}$$

where

$V_{ind}(f_i,d_{loop})$ is the induced voltage in a loop in the head at frequency f_i and at a distance d_{loop};

d_{loop} is the diameter of the loop in the head;

$B(f_i,d_{loop})$ is the magnetic B-field at frequency f_i and at a distance d_{loop}.

The induced current in the loop of the head due to the magnetic field can be calculated by Equation (D.6)

$$I_{eddy}(f_i,d_{loop}) = \frac{V_{ind}(f_i,d_{loop})}{\dfrac{\pi \cdot D_{loop}}{A \cdot \sigma(f_i)}} \tag{D.6}$$

where

$I_{eddy}(f_i,d_{loop})$ is the induced current in a loop of the head due to the magnetic field at frequency f_i and at a distance d_{loop};

A is the “wired” area of the loop in the head;

$\sigma(f_i)$ is the conductivity of the loop in the head at frequency f_i.

Subsequently, the current density in the loop of the head due to the magnetic field, at a certain frequency f_i and distance d_{loop}, can be calculated by Equation (D.7)

$$J_{\text{eddy}}(f_i, d_{\text{loop}}) = \frac{I_{\text{eddy}}(f_i, d_{\text{loop}})}{A_{\text{loop}}} = \frac{D_{\text{loop}} \cdot \sigma(f_i) \cdot \pi \cdot f_i \cdot B(f_i, d_{\text{loop}})}{2} \tag{D.7}$$

The internal induced electric field can be determined using the relation

$$J_{\text{eddy}}(f_i, d_{\text{loop}}) = \sigma(f_i) \cdot E(f_i, d_{\text{loop}}) \tag{D.8}$$

Finally, this gives the following expression for the internal electric field:

$$E_{\text{eddy}}(f_i, d_{\text{loop}}) = \frac{D_{\text{loop}} \cdot \pi \cdot f_i \cdot B(f_i, d_{\text{loop}})}{2} \tag{D.9}$$

D.2.2.2 The f_{mains} contribution of the induced current density due to the magnetic field

The measured B-field at the mains frequency and at a distance d = 0,3 m from the lighting equipment is approximately 60 nT. With D_{loop} = D_{head} = 0,21 m the following data can be calculated (see Table D.1):

Table D.1 – Induced internal electric field calculations

$f_i = f_{\text{mains}}$ Hz	$E_{\text{eddy}}(f_i,d)$ at f_{mains} and d = 0,3 m nA/m²	$E_{\text{Lim}}(f_i)$ at f_{mains} mA/m²	$\frac{E_{\text{eddy}}(f_i,d)}{E_{\text{Lim}}(f_i)}$ at f_{mains} and d = 0,3 m
50	0,99	0,02	49×10^{-6}
60	1,2	0 024	49×10^{-6}

Both the electric field limit and the induced electric field increase proportional with frequency (in this frequency range), therefore the relation in Table D.1 is constant.

It can be concluded that the induced electric field contribution in the head due to the magnetic field at the mains frequency and a measurement distance of d = 0,3 m can be neglected.

D.2.2.3 The 20 kHz to 10 MHz contribution of the induced electric field due to the magnetic field

The worst-case contribution of the electric field induced in the head due to the magnetic field in the frequency area from 20 kHz to 10 MHz and at a measurement distance d can be determined by using for instance the maximum possible level of radiated magnetic emissions of CISPR 15 [9]. According to CISPR 15 the maximum current induced by lighting equipment at the frequency f_i in the 2 m large loop antenna (LLA) is given by Figure D.3.

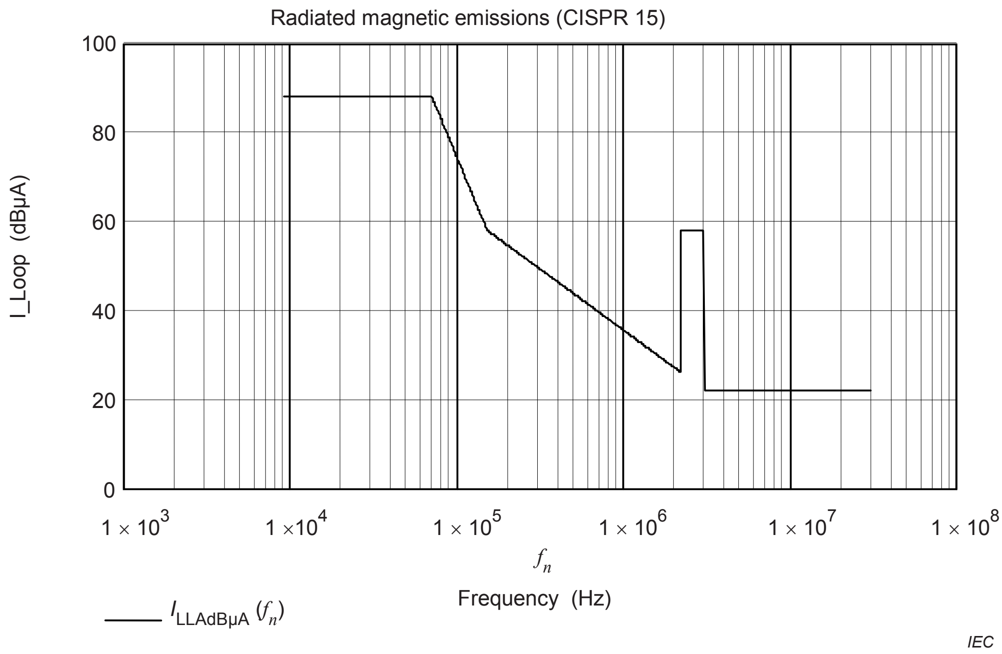


Figure D.3 – Maximum current in the 2 m LLA as function of the frequency

The maximum current at the frequency f_i in the 2 m LLA of Figure D.3 can be converted to the maximum B-field at the frequency f_i and at an arbitrary distance d.

The conversion can be explained as follows:

A virtual magnetic dipole with area A_{dipole} located at the centre of the 2 m LLA has a mutual inductance to the 2 m LLA of:

$$M = \frac{\mu_0 \cdot A_{\text{dipole}}}{D_{\text{LLA}}} \tag{D.10}$$

where

M	is the mutual inductance between the virtual magnetic dipole and the 2 m LLA;
A_{dipole}	is the area of the virtual magnetic dipole;
D_{LLA}	is the diameter of the 2 m LLA and equals 2 m.

The virtual magnetic dipole moment is $I_{\text{dipole}}(f_i) \cdot A_{\text{dipole}}$

where $I_{\text{dipole}}(f_i)$ is a virtual current at frequency f_i in the virtual magnetic dipole.

The induced voltage in the LLA is:

$$V_{\text{ind}}(f_i) = 2 \cdot \pi \cdot f_i \cdot M \cdot I_{\text{dipole}}(f_i) \tag{D.11}$$

The current in the LLA is:

$$I_{\text{LLA}}(f_i) = \frac{V_{\text{ind}}(f_i)}{2 \cdot \pi \cdot f_i \cdot L_{\text{LLA}}} = \frac{\mu_0 \cdot I_{\text{dipole}}(f_i) \cdot A_{\text{dipole}}}{L_{\text{LLA}} D_{\text{LLA}}} \tag{D.12}$$

where L_{LLA} is the inductance of the 2 m LLA and equals 9,65 µH

So, from the limit set to the current in the LLA, the virtual magnetic dipole moment $I_{\text{dipole}}(f_i) \cdot A_{\text{dipole}}$ can be calculated. From this virtual magnetic dipole moment the H-field strength in the direction where it is maxima can be calculated. The calculations are made up to 10 MHz, so the smallest wavelength is 30 m and the transition between near field and far field is at 30/2 π = 4,8 m. For EMF we are interested in the induced current density at a smaller distance, so all calculations are based on the near field condition where $H \approx 1/d^3$.The maximum field strength at distance d_{loop} can be expressed as:

$$H(f_i, d_{\text{loop}}) = \frac{I_{\text{dipole}}(f_i) \cdot A_{\text{dipole}}}{2 \cdot \pi \cdot d_{\text{loop}}^3} \tag{D.13}$$

where $d_{\text{loop}} = d + (D_{\text{head}}/2)$.

From this the maximum B-field at the frequency f_{i} and an arbitrary distance d_{loop} is defined as:

$$B(f_i, d_{\text{loop}}) = \frac{I_{\text{LLA}}(f_i) \cdot L_{\text{LLA}} \cdot D_{\text{LLA}}}{2 \cdot \pi \cdot d_{\text{loop}}^3} \tag{D.14}$$

In the worst case the B-fields in the x-, y- and z-direction all meet this maximum value. The resulting B-field can be calculated by Equation (D.13):

$$B(f_i, d_{\text{loop}}) = \frac{I_{\text{LLA}}(f_i) \cdot L_{\text{LLA}} \cdot D_{\text{LLA}} \cdot \sqrt{3}}{2 \cdot \pi \cdot d_{\text{loop}}^3} \tag{D.15}$$

Equation (D.7) can now be rewritten in Equation (D.16):

$$J_{\text{eddy}}(f_i, d_{\text{loop}}) = \frac{D_{\text{loop}} \cdot \sigma(f_i) \cdot \pi \cdot f_i}{2} \cdot \frac{I_{\text{LLA}}(f_i) \cdot L_{\text{LLA}} \cdot D_{\text{LLA}} \cdot \sqrt{3}}{2 \cdot \pi \cdot d_{\text{loop}}^3} \tag{D.16}$$

Or expressed in terms of internal electric field:

$$E_{\text{eddy}}(f_i, d_{\text{loop}}) = \frac{D_{\text{loop}} \cdot \pi \cdot f_i}{2} \cdot \frac{I_{\text{LLA}}(f_i) \cdot L_{\text{LLA}} \cdot D_{\text{LLA}} \cdot \sqrt{3}}{2 \cdot \pi \cdot d_{\text{loop}}^3} \tag{D.17}$$

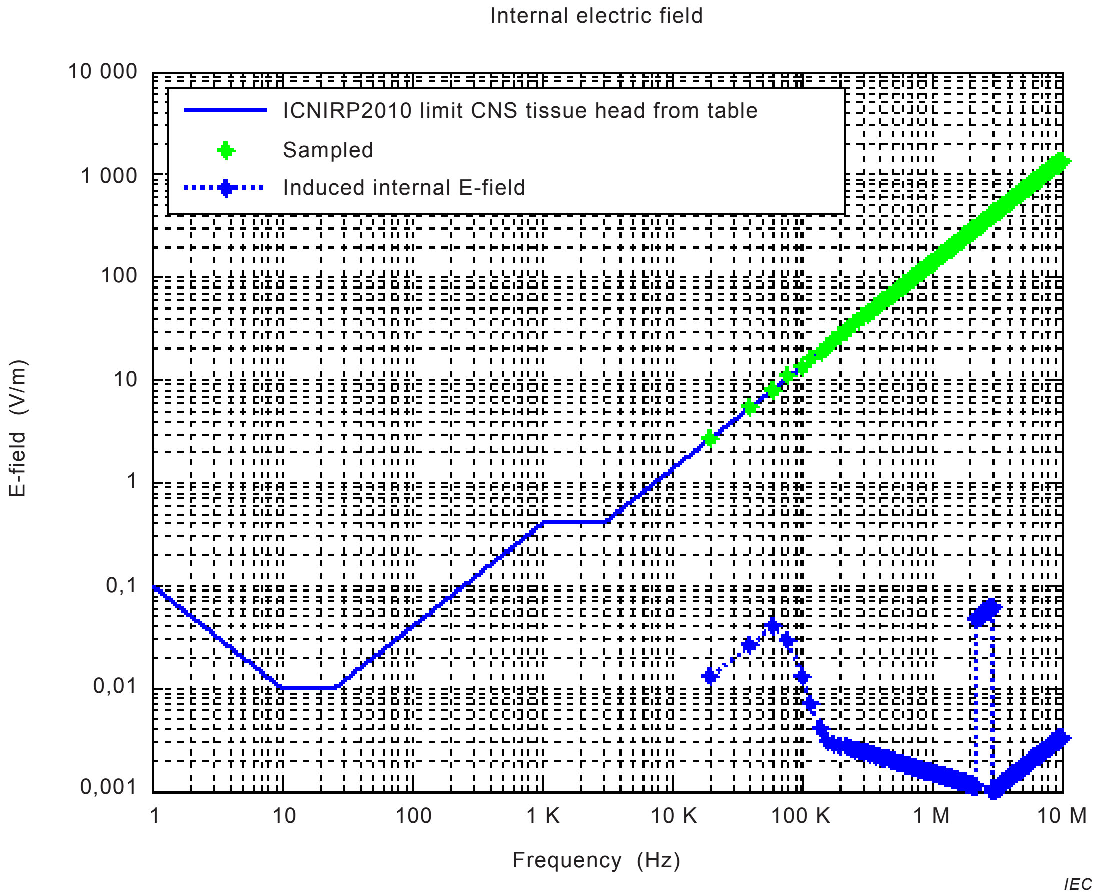


Figure D.4 – Induced internal electric field and associated limit levels

The worst-case contribution of the electric field in the head due to the magnetic field in the frequency area from 20 kHz to 10 MHz and at a distance d = 0,3 m can now be calculated by summing all the harmonics arising from the disturbance source inside the lighting equipment.

Figure D.4 depicts both the electric field limit and the induced electric field for this specific case. For a switched-mode power supply with a fundamental switching frequency of 20 kHz only the odd harmonics contribute. In this case:

$$\sum_{f_i=20kHz}^{10MHz} \frac{E_{\text{eddy}}(f_i, d_{loop})}{E_{\text{Lim}}(f_i)} \text{ and } \leq 0{,}02$$

This contribution is relatively small, and a similar small contribution may be expected if other EMC emission standards (other than CISPR 15) are taken as reference. Moreover, in this assessment a very conservative approach is taken, i.e. the unintended emission is present over the whole frequency range under consideration, and the emission-level is right at the limit at all these frequencies. This is very unlikely; in practice the unintended emission levels are near the limit only for a limited frequency range or even for just a few discrete spectral components. Furthermore, it should be noted that a worst case way of summation is applied, because possible phase relationships which are present in the case of harmonics are not taken into account. Figure D.5 shows as an example how the result of a magnetic field test using the LLA may look like.

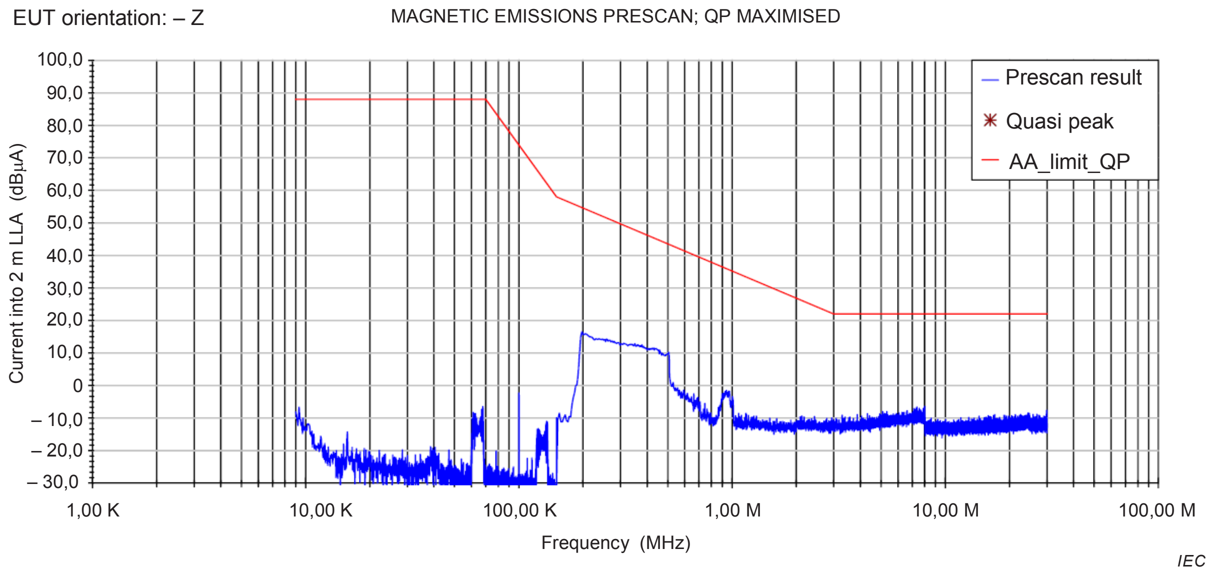


Figure D.5 – Example of magnetic-field test result using the LLA

Conclusion:

If lighting equipment complies with CISPR 15, the contribution from the magnetic field emission limit measured through the LLA is negligible, and Equation (D.4) can be simplified in Equation (D.18):

$$\frac{E_{\text{cap}}(f_{\text{mains}},d)}{E_{\text{Lim}}(f_{\text{mains}})}+\sum_{f_i=20\text{kHz}}^{10\text{MHz}}\frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)}\leq 1 \tag{D.18}$$

D.2.3 Induced electric field due to the electric field; $E_{\text{cap}}(f_i,d)$

D.2.3.1 General

The contribution of the electric field to the induced electric field in the head is measured by using a dummy person near the lighting equipment at a measurement distance d; according to Table A.1 and a position according to Annex B. The dummy person used is the homogenous body model as described in Figure C.3 of IEC 62311:2007.

It is assumed that the head of the dummy person is closest to the lighting equipment and the maximum current density (and thus electric field level) occurs in the neck. Therefore only the head (a metalized sphere with an outside diameter of D_{head} = 210 mm ± 5 mm) is used as a "current test head". The diameter of the neck D_{neck} = 110 mm, is used in the calculations of the internal electric field. Details of the "current-test-head" called "Van der Hoofden test head can be found in 5.5.

NOTE The current density in the neck is homogenous since the skin effect up to 10 MHz can be neglected.

D.2.3.2 The f_{mains} contribution of the induced internal electric field due to the electric field

The contribution of the mains to the induced internal electric field will be calculated based on the following worst-case construction: Lighting equipment is a large plate at V_{mains} with respect to ground (see Figure D.4).

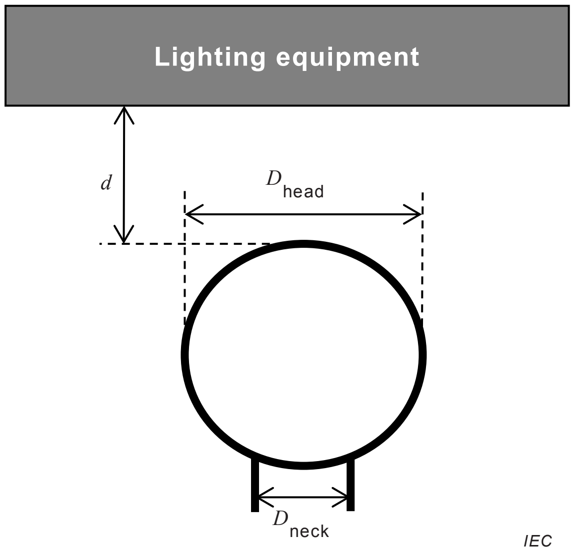


Figure D.6 – Distances of the head and measurement set-up

The parasitic capacitance between a large plate and a sphere can be calculated with the formulas from W.R. Smythe [5] (for the configuration see Figure D.6):

$$\alpha = \cosh^{-1}\left[2\cdot\left(1+\frac{2\cdot d}{D_{\text{head}}}\right)^{2}-1\right] \tag{D.19}$$

$$C_{\text{Sphere\_plate}} = 2\cdot\pi\cdot\varepsilon_0\cdot\frac{D_{\text{head}}^{2}}{2\cdot d+D_{\text{head}}}\cdot\sinh(\alpha)\cdot\lim_{N\to\infty}\sum_{n=1}^{N}\frac{1}{\sinh(n\cdot\alpha)} \tag{D.20}$$

In most practical situations N = 50 is sufficient.

With d = 0,3 m: $C_{\text{Sphere\_plate}}$ = 3 pF (see Figure D.7).

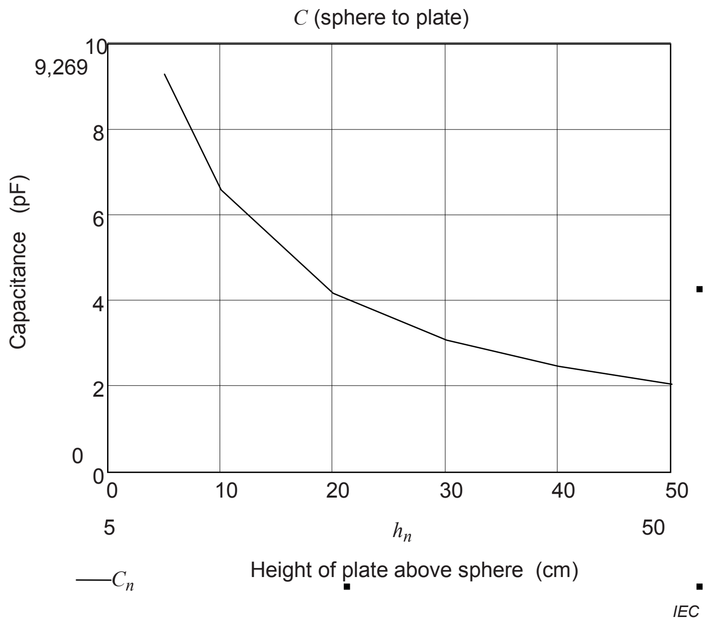


Figure D.7 – Plot of Equation (D.20)

The current density in the neck, caused by the mains can be calculated by Equation (D.21).

$$J_{\text{cap}}(f_{\text{mains}},d)=\frac{U_{\text{mains}}\cdot 2\cdot\pi\cdot f_{\text{mains}}\cdot C}{\frac{\pi}{4}\cdot D_{\text{neck}}^{2}}=661\cdot 10^{6}\cdot U_{\text{mains}}\cdot f_{\text{mains}}\cdot C \tag{D.21}$$

The resulting internal E-field in the neck can be calculated using Equation (D.8):

$$E_{\text{cap}}(f_{\text{mains}},d)=661\cdot 10^{6}\cdot\sigma(f_{\text{mains}})\cdot U_{\text{mains}}\cdot f_{\text{mains}}\cdot C \tag{D.22}$$

Equation (D.22) is calculated using $\sigma(f_{\text{mains}})$ = 0,09 and different mains frequencies and mains voltages. The results are given in Table D.2.

Table D.2 – Calculation main contributions

U_{mains} V	f_{mains} Hz	$E_{\text{cap}}(f_{\text{mains}},d)$ at f_{mains} and d = 0,3 m µA/m²	$E_{\text{Lim}}(f_{\text{mains}})$ mA/m²	$\frac{E_{\text{cap}}(f_{\text{mains}},d)}{E_{\text{Lim}}(f_{\text{mains}})}$ at f_{mains} and d = 0,3 m
230	50	0,25	0,02	0,013
120	60	0,16	0,024	0,007
277	60	0,37	0,024	0,015

The calculation results, as depicted in the last column of Table D.2, show that the contribution of the mains can be neglected and Equation (D.18) can be simplified as:

$$\sum_{f_i=20\text{kHz}}^{10\text{MHz}}\frac{E_{\text{cap}}(f_i,d)}{E_{\text{Lim}}(f_i)}\leq 1 \tag{D.23}$$

The left term of this Equation (D.23) is equal to the factor F, see 3.1.4 and Equation (E.7).

D.2.3.3 The 20 kHz to 10 MHz contribution of the internal electric field due to the electric field

The contribution of the electric field to the internal electric field in the head in the frequency range 20 kHz to 10 MHz has to be measured with an EMI-receiver according to Figure 3 and Equation (D.23).

The frequency step of the summation is determined by using CISPR 16-1-1. According to CISPR 16-1-1, the IF-filter of the receiver has the transfer function of Equation (D.24):

$$H(f):=\left[\frac{2}{1+\left(1+j\cdot\frac{f}{B_6}\cdot 2\sqrt{2}\right)^{2}}\right]^{2} \tag{D.24}$$

The modulus of Equation (D.24) is expressed by Equation (D.25).

$$|H(f)|:=\frac{1}{1+\left(\frac{2f}{B_6}\right)^{4}} \tag{D.25}$$

The frequency step for the amplitude addition is defined by Equation (D.26):

$$f_{\text{step\_ampl}} = \int_{-\infty}^{\infty} \left| H(f) \right| \cdot df \tag{D.26}$$

Solving Equation (D.26) results in a frequency step for the amplitude addition that equals 1,11 times B_6, see Table D.3.

Table D.3 – Frequency steps for the amplitude addition that equals 1,11 times B_6

Frequency range	B_6 according to CISPR 16-1-1	$f_{\text{step\_ampl}}$
20 kHz to 150 kHz	200 Hz	220 Hz
150 kHz to 10 MHz	9 kHz	10 kHz

Equation (D.23) can be rewritten as:

$$\sum_{\substack{f_i = 20\text{kHz} \\ \text{Step}=220\text{Hz}}}^{150\text{kHz}} \frac{E_{\text{cap}}(f_i, d)}{E_{\text{Lim}}(f_i)} + \sum_{\substack{f_i = 150\text{kHz} \\ \text{Step}=10\text{kHz}}}^{10\text{MHz}} \frac{E_{\text{cap}}(f_i, d)}{E_{\text{Lim}}(f_i)} \leq 1 \tag{D.27}$$

A practical measurement and assessment method to evaluate Equation (D.27) is given in Annex E.

D.3 Thermal effects from 100 kHz to 300 GHz

D.3.1 General

The thermal effects are deemed to comply if the power of radiated emissions is ≤ 20 mW according to IEC 62479. In this Clause D.3 it will be shown that the power of the radiated emissions is much less than the 20 mW low-power limit from IEC 62479 for any lighting equipment that complies with international EMC standards such as CISPR 15. As an example, in this subclause, the contribution to the thermal effects will be calculated using the CISPR 15 emission limits.

The proof that the radiated power is ≤20 mW starts with Equation (D.28):

$$P_{\text{rad,max}} = \sum_{100\text{ kHz}}^{300\text{ MHz}} P_{\text{rad,max}}(f_i) = \sum_{100\text{ kHz}}^{30\text{ MHz}} P_{\text{rad,max}}(f_i) + \sum_{30\text{ MHz}}^{300\text{ MHz}} P_{\text{rad,max}}(f_i) \tag{D.28}$$

The frequency step of the summation is determined by using CISPR 16-1-1 as explained in D.2.3.3.

The frequency step for the power addition can be defined by Equation (D.29):

$$f_{\text{step\_power}} = \int_{-\infty}^{\infty} \left| H(f) \right|^2 \cdot df \tag{D.29}$$

Solving Equation (D.29) results in a frequency step for the power addition that equals 0,833 times B_6, see Table D.4.

Table D.4 – Frequency steps for the power addition that equals 0,833 times B_6

Frequency range	B_6 according to CISPR 16-1-1	f_{step_power}
100 kHz to 150 kHz	200 Hz	167 Hz
150 kHz to 30 MHz	9 kHz	7,5 kHz
30 MHz to 300 MHz	120 kHz	100 kHz

D.3.2 The 100 kHz to 30 MHz contribution to the thermal effects

The maximum terminal voltage (TV) of the conducted emission is set by CISPR 15. The radiated emission is maximum if this TV is caused by common-mode-current only and if the mains cord acts as a half wavelength dipole at any frequency. From a half wavelength dipole it is known that the impedance for radiation is 73 Ω. From this the maximum radiated power in this frequency range can be calculated by using Equation (D.30).

$$P_{\text{rad,max}}(100\,\text{kHz to }30\,\text{MHz}) = \sum_{100\,\text{kHz}}^{30\,\text{MHz}} I_{\text{cm}}^2(f_i)\cdot 73 \tag{D.30}$$

where

$P_{\text{rad,max}}(100\,\text{kHz to }30\,\text{MHz})$ is the maximum radiated power [W] between 100 kHz to 30 MHz;

$I_{\text{cm}}(f_i)$ is the common mode current [A] at frequency f_i.

By using Kirchhof's law, Equation (D.30) can be rewritten as:

$$P_{\text{rad,max}}(100\text{ kHz to 30 MHz}) = \sum_{\substack{f_i=100\text{ kHz}\\ Step=167\text{ Hz}}}^{150\text{ kHz}} \left(\frac{TV_{\text{lim}}(f_i)}{50/2}\right)^2 \cdot 73 + \sum_{\substack{f_i=150\text{ kHz}\\ Step=7,5\text{ kHz}}}^{30\,MHz} \left(\frac{TV_{\text{lim}}(f_i)}{50/2}\right)^2 \cdot 73$$

(D.31)

with

$TV_{\text{lim}}(f_i)$ is the terminal voltage limits according to CISPR 15 at frequency f_i.

Solving Equation (D.31) results in:

$$P_{\text{rad,max}}(100\,\text{kHz to }30\,\text{MHz}) \le 5{,}98\,[\text{mW}]$$

This contribution is relatively small, and a similar small contribution may be expected if other EMC emission standards (other than CISPR 15) are taken as reference. It should be noted also that the model in this calculation is very conservative, as it assumes that the DUT and the mains cable behave as a half-wave dipole antenna at all frequencies between 100 kHz and 30 MHz. In reality, the DUT plus the cable is a very inefficient antenna with a radiation resistance that is much less than the radiation resistance from a matched half-wave dipole (see for instance Balanis [8] for the radiation resistance of small dipole antennas). Moreover, in this assessment a very conservative approach is taken, i.e. the unintended emission is present over the whole frequency range under consideration, and the emission-level is right at the limit at all these frequencies. This is very unlikely; in practice the unintended emission levels are near the limit only for a limited frequency range or even for just a few discrete spectral components. Also, it should be noted that a worst case way of summation is applied, because possible phase relationships which are present in the case of harmonics are not taken into account. Figure D.8 shows as an example on how the result of a conducted emission test may look like in practice.

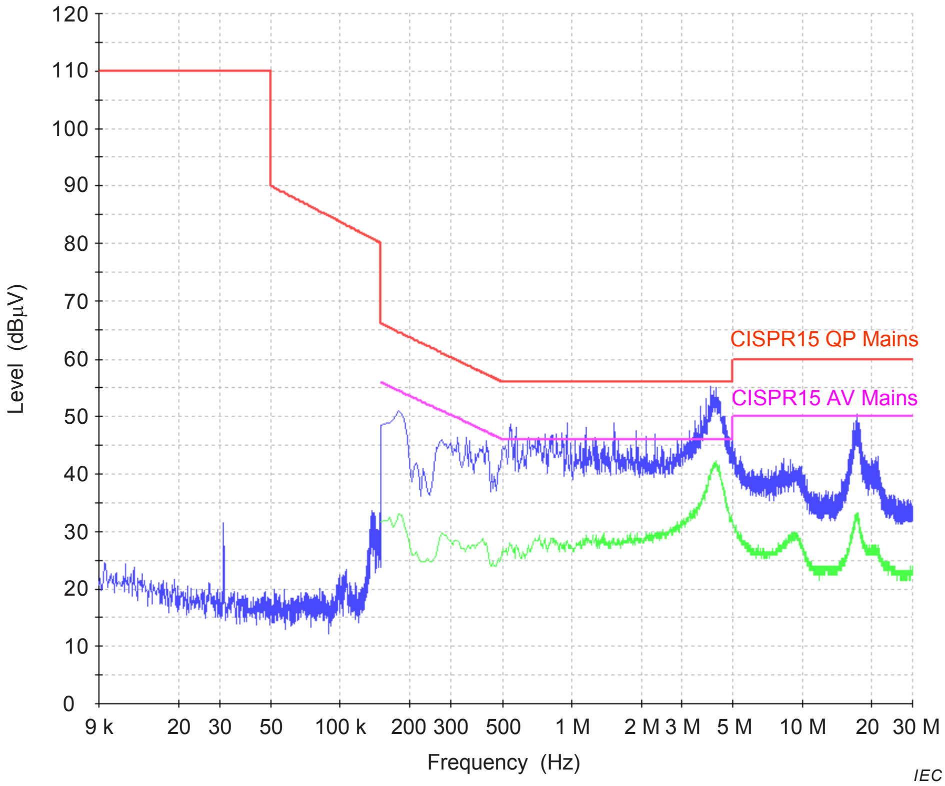


Figure D.8 – Example of the CM-current measured using a conducted emission test

Conclusion:

The thermal contribution $P_{\text{rad,max}}(100\,\text{kHz to }30\,\text{MHz}) \approx 0$ and can therefore be neglected.

D.3.3 The 30 MHz to 300 MHz contribution to the thermal effects

If, for example the lighting equipment complies with the radiated emissions requirements according to CISPR 15, then in the worst case, at any frequency the lighting equipment radiates as a half wave dipole. The maximum radiated power in the main direction of the field is given by Equation (D.32):

$$P_{\text{rad,max}}(30\text{ MHz to }300\text{ MHz}) = \sum_{\substack{f_i = 30\text{ MHz} \\ Step=100\text{ kHz}}}^{300\text{ MHz}} \left(\frac{r \cdot E_{\text{lim}}(f_i,r)}{7}\right)^2 \quad \text{(D.32)}$$

where

$E_{\text{lim}}(f_i,r)$ is the limit of the E-field [V/m] at frequency f_i.

According to CISPR 15 the field strength limits are given in Table D.5:

Table D.5 – Field strength limits according to CISPR 15

Frequency range MHz	E_{lim} dBµV/m	E_{lim} µV/m	r m
30 to 230	30	31,6	10
230 to 1 000	37	70,8	10

Solving Equation (D.32) results in:

$$P_{\mathrm{rad,max}}(30\,\mathrm{MHz\ to\ }300\,\mathrm{MHz}) \leq 0{,}10\,[\mathrm{mW}]$$

Again, this contribution is very small, and a similar small contribution may be expected if other EMC emission standards (other than CISPR 15) are taken as reference. It should be noted also that the model in this calculation is very conservative, as it assumes that the DUT and the mains cable behave as a half-wave dipole antenna over this frequency range. In reality, the DUT plus the cable is a very inefficient antenna with a radiation resistance that is much less than the radiation resistance from a matched half-wave dipole (see for instance Balanis [8]). Moreover, in this assessment a very conservative approach is taken, i.e. the unintended emission is present over the whole frequency range under consideration, and the emission-level is right at the limit at all these frequencies. Again, this is very unlikely; in practice the unintended emission levels are near the limit only for a limited frequency range or even for just a few discrete spectral components. Also, it should be noted that a worst case way of summation is applied, because possible phase relationships which are present in the case of harmonics are not taken into account.

Conclusion:

The thermal contribution $P_{\mathrm{rad,max}}$ between 30 MHz and 300 MHz is about 0 and can therefore be neglected.

D.3.4 Overall conclusion for the contribution to thermal effects

The thermal contribution in the range from 100 kHz to 300 MHz is negligible, and therefore it is deemed to comply with the thermal effects requirements according ICNIRP and IEEE if the lighting equipment does not include intentional radiators. In case the lighting equipment includes intentional radiators, then an additional compliance criterion applies. See Annex I and Clause 4 and Clause 7 for details.

Annex E
(normative)

Practical internal electric-field measurement and assessment method

E.1 Measurement of induced internal electric field

The internal electric field has to be measured from 20 kHz to 10 MHz according to Clause 5.

This Annex E describes an example based on an EMI receiver that generates output data in a matrix (spread sheet) where the frequency (MHz) is stored in column 0 and the measured voltage (dBμV) in column 1. This data output has to be processed by the calculation program of Clause E.2.

E.2 Calculation program

The measured data is a matrix with the frequency f_n (MHz) stored in column 0 and the measured voltage $V(f_n)$ (dBμV) in column 1.

The measured voltage $V(f_n)$ (dBμV) of column 1 has to be transferred into $V(f_n)$ (V), using Equation (E.1).

$$V(f_n)[\text{V}] = 10^{\frac{V(f_n)[\text{dBμB}]}{20}} \cdot 10^{-6} \tag{E.1}$$

The voltage $V(f_n)$ (V) has to be transferred into a current $I_{\text{cap}}(f_n)$ (A), using the transfer function $g(f_n)$ (V/A), determined by the protection network of 5.4, given in Equation (E.2)

$$g(f_n) = \frac{V(f_n)}{I_{\text{cap}}(f_n)} = \frac{50}{\sqrt{1 + (4\pi \cdot f_n)^2}} \tag{E.2}$$

The current density $J_{\text{cap}}(f_n)$ (A/m^2) is given by Equation (E.3)

$$J_{\text{cap}}(f_n) = \frac{V(f_n)}{g(f_n) \cdot A_{\text{neck}}} \tag{E.3}$$

where

$$A_{\text{neck}} = \frac{\pi}{4} \cdot 0{,}11^2$$

The measured current density $J_{\text{cap}}(f_n)$ can be expressed in terms of internal electric field:

$$E_{\text{cap}}(f_n) = \frac{V(f_n)}{\sigma(f_n) \cdot g(f_n) \cdot A_{\text{neck}}} \tag{E.4}$$

where the values for the conductivity $\sigma(f_n)$ as function of the frequency can be calculated by using the following Equation (E.5)

$$\sigma(f_n) = a.(f_n \cdot 10^6)^b + c \tag{E.5}$$

where a = 3,629·10^{-5}, b = 0,528 3 and c = 0,108 7.

Equation (E.5) gives an approximation of the values between 10 kHz and 10 MHz given in Table E.1.

Table E.1 – Conductivity as a function of frequency (see Table C.1 of IEC 62311:2007)

	Conductivity S/m						
Frequency	**10 Hz**	**100 Hz**	**1 000 Hz**	**10 kHz**	**100 kHz**	**1 MHz**	**10 MHz**
Brain (grey matter)	0,03	0,09	0,10	0,11	0,13	0,16	0,29

The induced electric field $E_{\text{cap}}(f_n)$ has to be rated with the limit value $E_{\text{Lim}}(f_n)$ and has to be summated to determine the factor F, as given by Equation (E.6)

$$F = \sum_{f=20kHz}^{10MHz} \frac{E_{\text{cap}}(f_n)}{E_{\text{Lim}}(f_n)} \tag{E.6}$$

where

$E_{\text{Lim}}(f_n) = 1{,}35 \cdot 10^2 \cdot f_n$ and f_n in MHz

Step size is defined in Table 2.

E.3 Compliance criterion for the Van der Hoofden head test

With the results from the conservative estimations presented in Annex D, the summed relative internal electric field resulting from the four terms of Equation (D.4) can be summarized as follows:

(D.4.a)		(D.4.b)		(D.4.c)		(D.4.d)		(D.4)	
Subclauses D.2.2.1 and D.2.2.2 negligible	+	Subclause D.2.2.3 negligible	+	Subclause D.2.3.2 negligible	+	Subclause D.2.3.3 and Annex E F to be measured using the Van der Hoofden head	≤	1	(E.7)

When filling out the result F of the Van der Hoofden test, Equation (E.7) reduces to the following compliance criterion:

The measured, weighted and summarized induced internal electric field compliance factor F due to the external electric field in the frequency range 20 kHz to 10 MHz shall not exceed the value of 1; see Equation (E.8).

$$F \leq 1 \tag{E.8}$$

NOTE An additional compliance criterion might be applicable in case the equipment contains intentional radiators (see Annex I and Clause 4 and 7 for details).

Annex F
(normative)

Protection network

F.1 Calibration of the protection network

The calibration shall be done in a similar way to the calibration of an artificial mains network (V-Network) as described in CISPR 16-1-2 [10].

The input and output port of the protection network are not matched to the 50 Ω characteristic impedance of the network analyser (NWA). Because of that property the calibration shall be done in the following two steps:

Step 1:

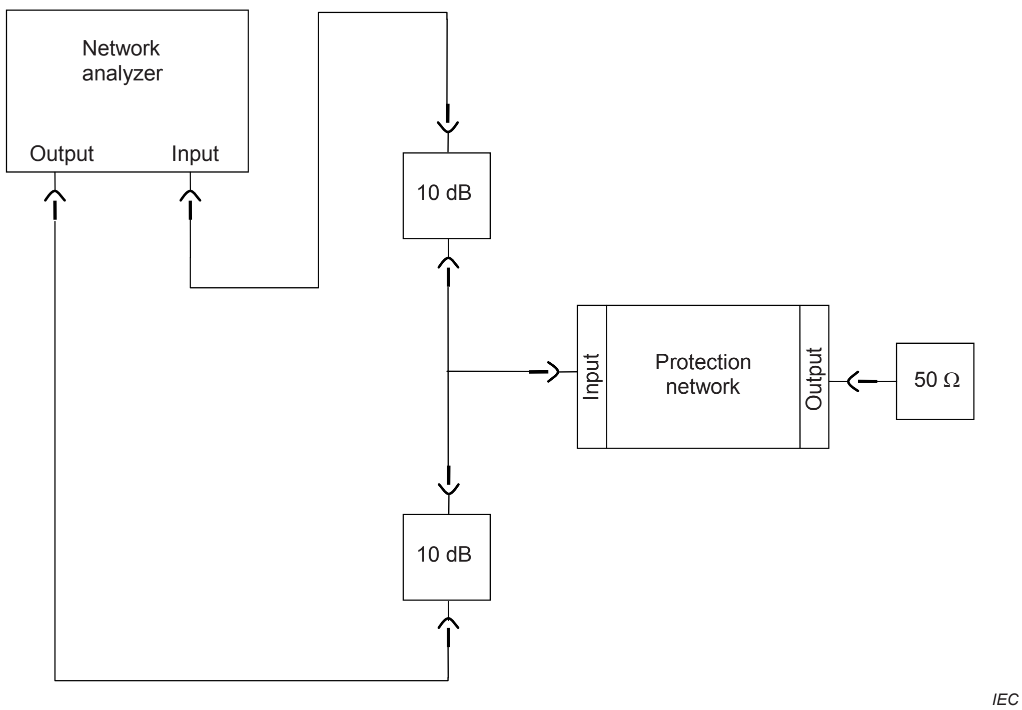


Figure F.1 – Test set-up for normalization of the network analyser

After the network analyser is calibrated with the test set-up shown in Figure F.1, the circuit has to be changed into the new configuration shown in Figure F.2.

Step 2:

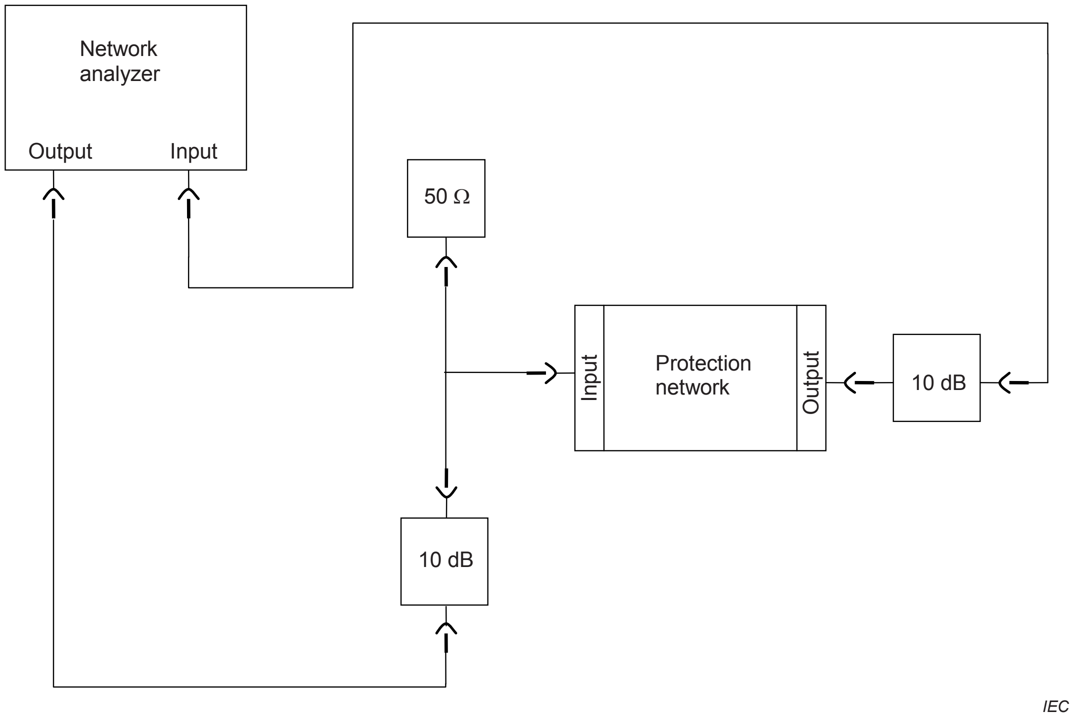


Figure F.2 – Test set-up for measurement of the voltage division factor using a network analyser

After the transfer function is measured with the network analyser, it has to be compared with the theoretical characteristic.

F.2 Calculation of the theoretical characteristic of the protection network

The transfer function given in Equation (1) in 5.5 cannot be used for the calibration. Therefore the calculation of the theoretical characteristic is given here.

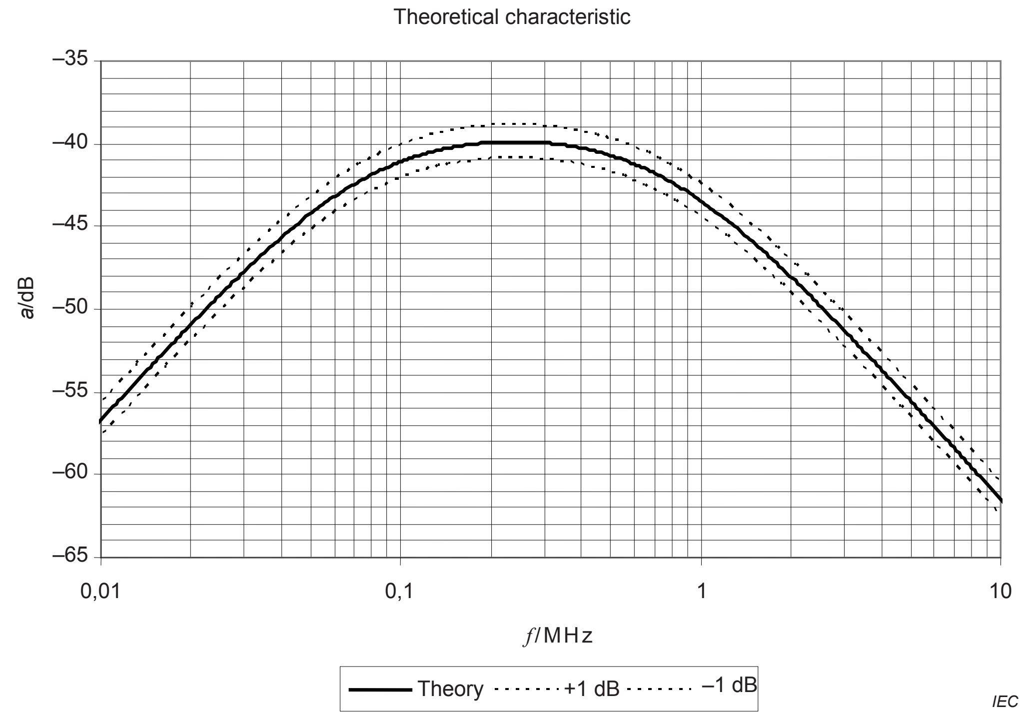
The theoretical transfer function (see Figure F.3) of the protection network for calibration with a network analyser is given by Equation (F.1). All values except the R_{NWA} (the input impedance R_{NWA} of the network analyser is typically 50 Ω) can be taken from Figure 2.

$$a(f) = 20 \bullet \log\left(\frac{|V_{out}(f)|}{|V_{in}(f)|}\right) \tag{F.1}$$

$$R_{2NWA} = R_2 + R_{NWA} \tag{F.2}$$

$$|V_{out}(f)| = \frac{1}{4}\sqrt{\left(\left(\frac{R_{2NWA}}{1+(\omega C_2 R_{2NWA})^2}\right)^2 + \left(\frac{\omega C_2 R_{2NWA}{}^2}{1+(\omega C_2 R_{2NWA})^2}\right)^2\right)} \tag{F.3}$$

$$|V_{in}(f)| = \sqrt{\left(\left(R_1 + \frac{R_{2NWA}}{1+(\omega C_2 R_{2NWA})^2}\right)^2 + \left(\frac{\omega C_2 R_{2NWA}{}^2}{1+(\omega C_2 R_{2NWA})^2} + \frac{1}{\omega C_1}\right)^2\right)} \tag{F.4}$$



The maximum allowed deviation in the picture is set to ±1 dB.

Figure F.3 – Calculated theoretical characteristic for the calibration of the protection network

Annex G
(informative)

Measurement instrumentation uncertainty

The main uncertainty components for the measured voltage at the output terminal of the protection network have been identified and estimated. All assumptions made are documented in Table G.2 and referenced as notes in the actual uncertainty calculation Table G.1.

The measured voltage V is calculated to:

$$V = V_{\mathrm{r}} + L_{\mathrm{c}} + \delta V_{\mathrm{sw}} + \delta V_{\mathrm{pa}} + \delta V_{\mathrm{pr}} + \delta V_{\mathrm{nf}} + \delta M + \delta g + \delta D + \delta d + \delta l \qquad \text{(G1)}$$

Table G.1 – Uncertainty calculation for the measurement method described in Clauses 5 and 6 in the frequency range from 20 kHz to 10 MHz

Input quantity [a]	X_i	Uncertainty of x_i		$u(x_i)$	c_i	$c_i\,u(x_i)$
		dB	Probability distribution function	dB		dB
Receiver reading (1)	V_{r}	± 0,1	k = 1	0,10	1	0,10
Attenuation: Protection network – receiver (2)	L_{c}	± 0,1	k = 2	0,05	1	0,05
Receiver corrections:						
Sine wave voltage (3)	δV_{sw}	± 1,0	k = 2	0,50	1	0,50
Pulse amplitude response (4)	δV_{pa}	± 0,0	Rectangular	0,00	1	0,00
Pulse repetition rate response (5)	δV_{pr}	± 0,0	Rectangular	0,00	1	0,00
Noise floor proximity (6)	δV_{nf}	± 0,0		0,00	1	0,00
Mismatch: Protection network – receiver (7)	δM	± 0,085	U-shaped	0,06	1	0,06
Transfer function protection network (8)	δg	± 1,0	Rectangular	0,50	1	0,58
Distance between test-head and DUT (9)	δD	–0,367 / +0,352	k = 1	0,36	1	0,36
Diameter of the test-head (10)	δd	–0,423 / +0,365	k = 1	0,39	1	0,39
Length of the ordinary cable (11)	δl	± 0,0		0,00		0,00
Combined measurement uncertainty: u_{c}=						0,94 dB
Expanded measurement uncertainty: 2 u_{c} (V) =						± 1,88 dB

[a] The numbers in brackets refer to the comments listed in Table G.2.

Table G.2 – Comments and information to Table G.1

Comments	Reference to Clause A.5 of CISPR 16-4-2:2003 [11]	Used data for calculations/statement
1) Random fluctuation of receiver reading	Note 1	CISPR 16-4-2:2003, Table A.1
2) Uncertainty of the cable loss measurement	Note 2	CISPR 16-4-2:2003, Table A.1
3) Uncertainty of the receiver sine wave correction	Note 4	CISPR 16-4-2:2003, Table A.1
4) Uncertainty of the receiver pulse amplitude response correction	–	Because there are only sine wave signals and their harmonics, the pulse amplitude response can be neglected.
5) Uncertainty of the receiver pulse repetition rate response correction	–	Because there are only sine wave signals and their harmonics, the pulse amplitude response can be neglected.
6) Uncertainty of the receiver noise floor influence	Note 6	CISPR 16-4-2:2003, Table A.1
7) Uncertainty of the mismatch between receiver and protection network	Note 7	CISPR 16-4-2:2003, Table A.1
8) Transfer function tolerance of the protection network. Specified as ± 1 dB of the theoretical curve.	–	–
9) Uncertainty due to the tolerance in the distance between the test head and the device under test (DUT)	–	6.3 Measurement distance
10) Uncertainty of the production tolerance test head	–	5.5 Measurement equipment requirements
11) Uncertainty of the cable length can be neglected	–	An experiment showed, that the mistake between 0,2 m and 2,5 m is less than 0,8 %. According to 6.4 (measurement set-up) the length of the cable (0,3 m) can vary ± 0,03 m. Because of that specification the mistake should be less than 0,2 %.

Annex H
(informative)

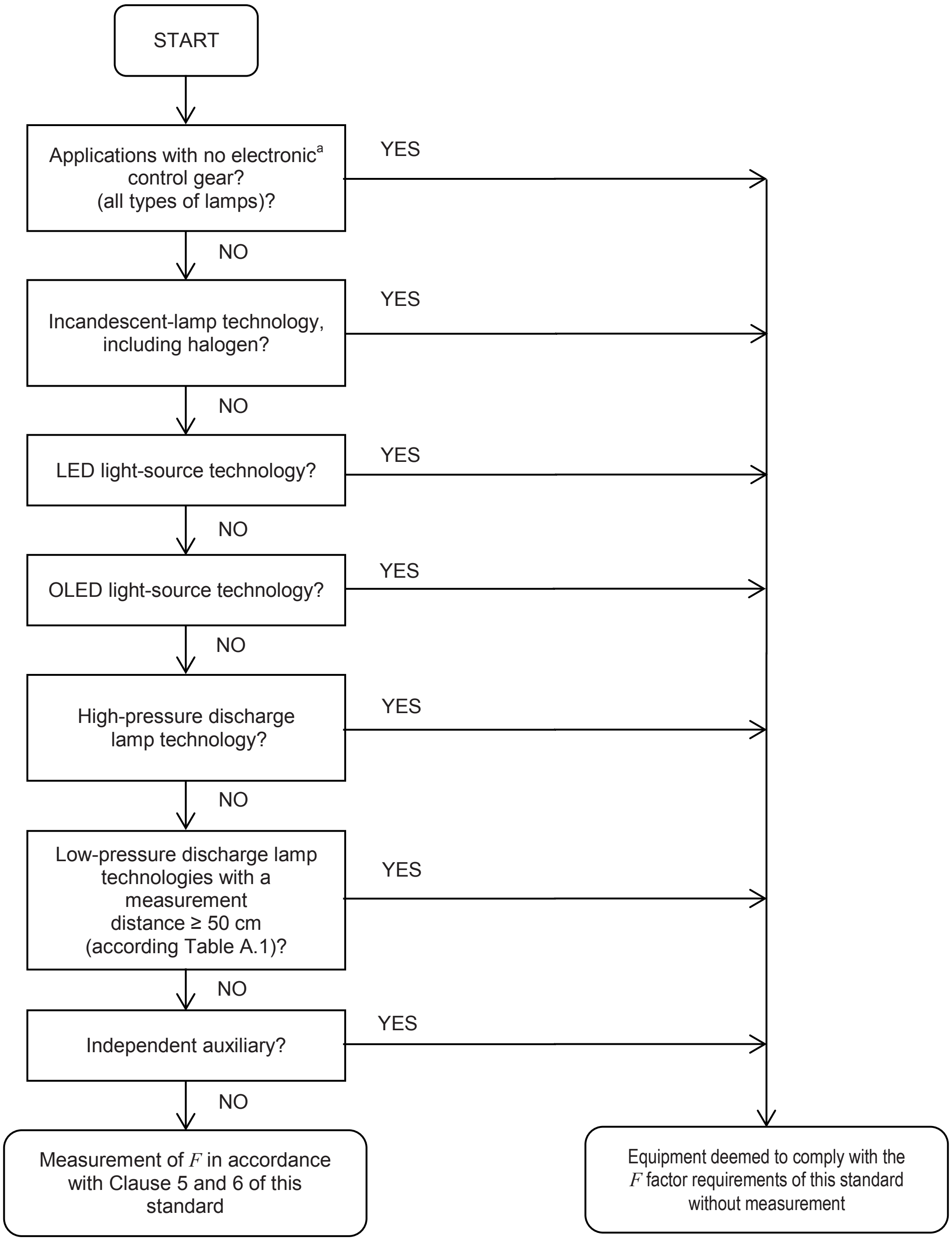
Equipment deemed to comply

In Germany an EMF measurement campaign of a large sample of lighting equipment has been executed with the Van der Hoofden head test. The factor F has been measured in accordance with the previous edition of this standard. The results have been reported in IEC TR 62493-1 [7]. The results show that out of 161 measured luminaires with different lamp technologies no luminaire was above the limit. Moreover, for the majority of the lighting equipment, the factor F measured is just a few percent of the limit value. From the retrospective analysis in in IEC TR 62493-1 [7], it is obvious that the low values of F can be predicted quite well from the physical properties and technologies of the equipment.

There is only one dominating effect on the result of the compliance factor F, i.e. the capacitive coupling between the lamp driven in the audio frequency range and the Van der Hoofden head. For a given distance and geometry, as given in the measurement setup, the signal is proportional to the lamp voltage and increases with the lamp dimension. When a fixture with a large lamp passes with considerable margin to the limit, then any lamp, which is smaller or which has a lower operating voltage will have even higher margin to the limit. All similar constructions will show similar results. All lighting applications with small lamps like LED, OLED, halogen or HID have proven to be far away from the limit.

Hence, unnecessary testing of lighting equipment can be avoided provided that certain physical or technology properties of the equipment are known upfront. The flow chart in Figure H.1 can be applied to determine whether certain categories of lighting equipment is deemed to comply without testing.

For technologies or applications not mentioned in Figure H.1 it is recommended to determine the compliance factor F.



[a] All kind of igniters, starters, switches, dimmers (including phase control units e.g. triac, GTO) and sensors are not considered as electronic controlgear

Figure H.1 – Flow chart to determine applicability deemed to comply without *F* factor measurement

Annex I
(informative)

Intentional radiators

I.1 General

As more lighting equipment might be equipped with intentional radio-frequency radiators, the EMF exposure assessment should take into account intentional RF sources as well (see 4.3 and Clause 7). This annex addresses the options and issues associated with the EMF assessment of intentional radiators in lighting equipment.

I.2 Intentional radiators in lighting equipment

Intentional radiating sources that might be applied in lighting equipment may be used for controlling and/or sensing purposes. Such wireless sources apply frequency ranges that are generally above 30 MHz and below 3 GHz. Table I.1 gives an overview of wireless technologies that could be applied in lighting systems. Also the basic properties such as frequency range, maximum radiated power and duty cycles are given.

EXAMPLE Zigbee and several proprietary wireless systems are used in the ISM frequency band 433 MHz, 2.4 GHz (worldwide), 915 MHz (Americas and Australia) and 868 MHz (Europe) ISM bands.

From Table I.1 we see that different ways of specifying total radiated power may be used. EIRP is the equivalent isotropically radiated power which is the product of the input power P of an antenna and the maximum antenna gain G, whereas ERP is the effective radiated power, which is the EIRP divided by the gain of an isotropic antenna.

The maximum radiated RF power is an important parameter for exposure assessment.

I.3 Properties of antennas in lighting applications

Antennas installed in lighting applications are typically low-gain antennas. It is often a dipole-type of antenna integrated in a luminaire near a ceiling (Figure I.1a)), which can be considered as an antenna near a conductive ground plane (Figure I.1b)) or a monopole on a ground plane. Hence, effectively the antenna behaves approximately as a dipole antenna. A dipole antenna has a doughnut-shaped omni-directional radiation pattern and a maximum gain G of 1,64 (Figure I.2 a) and b)). Due to ground-plane effects, the gain may increase up to a value of approximately G equals 4. Figure I.2 gives an example of the field distribution of a dipole in free space and a dipole at a certain distance from the ceiling, which is modelled as a perfectly conducting ground plane. The model applies the analytical formulas for a dipole and its image [I.5].The result shows an increase of the field level in certain directions and the occurrence of lobes, depending on the orientation of the dipole.

The exposure distance for different types of lamps ranges from 0,05 m up to 2 m (Table A.1). The frequency range of wireless technologies applied in lighting equipment is in the range from 300 MHz to 3 GHz. Hence the wavelength λ varies from 1 m to 0,1 m.

For non-directional (dipole-type) of antennas, the far-field region where the field decays with $1/d$ is reached at a distance d from the antenna, which satisfies

$$d > d_{nf-ff} = \lambda / 2\pi \qquad \text{(I.1)}$$

Table I.1 – Overview of wireless radio technologies that might be applied in lighting systems

Wireless technology name (standard)	**Standard**	**Freq. band**	**Max power** dBm	**Max power** [a] mW	**Duty cycle** [b]
ISM-band 2,4 GHz	Radio regulation ITU-R	2,4 GHz to 2,5 GHz	30 dBm (US) 20 dBm (Europe)	1 W (US) 100 mW (Europe)	n.a.
W-PAN Zigbee	IEEE 802.15.4-2006 application RF4CE	2 402 MHz to 2 480 MHz	0 dBm to 20 dBm	1 mW to 100 mW	varying typical 1 % to 5 %
W-PAN Bluetooth 4.0 (802.15.1)	Class I	2 402 MHz to 2 480 MHz	20 dBm	100 mW 76 mW average	76 % [c]
	Class II	2 402 MHz to 2 480 MHz	4 dBm to 10 dBm	2,5 mW to 10 mW 1,9 mW average	76 %
	Class III	2 402 MHz to 2 480 MHz	0 dBm	1 mW 0,76 mW average	76 %
	BTLE (Low Energy)	2 402 MHz to 2 480 MHz	10 dBm	10 mW	76 %
W-LAN	IEEE 802.11	2,45 GHz ISM 2 400 MHz to 2 483,5 MHz	20 dBm (EIRP)	100 mW (EIRP)	100 %
	IEEE 802.11b (indoor/outdoor)	2,45 GHz ISM 2 400 MHz to 2 483,5 MHz	20 dBm (EIRP)	100 mW (EIRP)	100 %
	IEEE 802.11a	5 150 MHz to 5725 MHz (Europe) 5 150 MHz to 5825 MHz (USA)	16 dBm, 23 dBm, 29 dBm with 6 dBi		
		indoor 5,25 GHz	23 dBm (EIRP)	200 mW (EIRP)	100 %
		indoor/outdoor 5,6 GHz	30 dBm (EIRP)	1000 mW (EIRP)	100 %
	IEEE 802.11g	2,45 GHz 2 400 MHz to 2 483,5 MHz	20 dBm (EIRP)	100 mW (EIRP)	100 %
	IEEE 802.11n	2,45 GHz	20 dBm (EIRP)	100 mW (EIRP)	100 %
KNX-RF	EN50090-5-3	868,0 MHz to 870,0 MHz	10 dBm 14 dBm max	10 mW 25 mW max	1 %

[a] Maximum power is the average value determined as specified in 5.7.3 of ETSI EN 300 328:2006 [I.3]; this ETSI standard requires to determine the EIRP as if the duty cycle were 100 %.

[b] The actual duty cycle may be less.

[c] Ratio of actual transmitted time-averaged power to the maximum power is maximal 0,76 [I.4]

Hence for the above-mentioned frequency range, the near-field to far-field transition distance, ranges from approximately 1/6 m to 1/60 m.

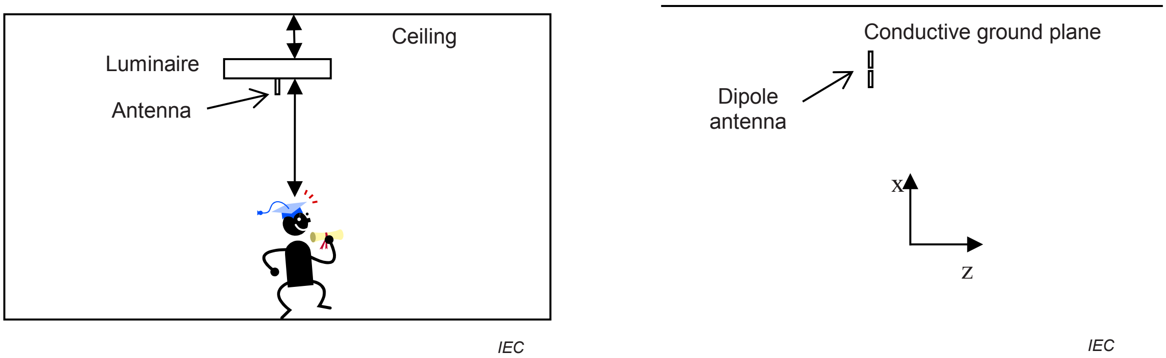
In the far-field region, the electric field E can be calculated using the following formula:

$$E(d) = \frac{\sqrt{30PG}}{d} \tag{I.2}$$

where, P is the power fed into the antenna, and G is the gain of the antenna.

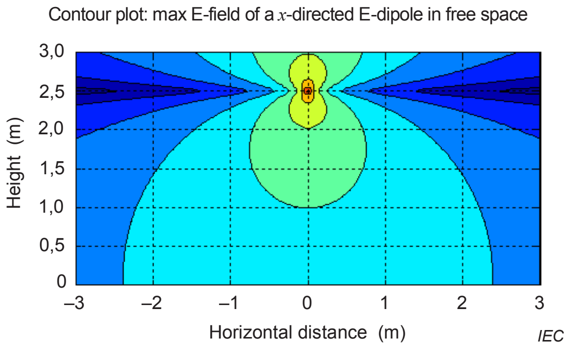
Figure I.3 gives an example of the field resulting from the analytical formula for a dipole in free-space [I.5], compared with the far-field approximation of Equation (I.2). Introducing this into the far-field condition of Equation (I.1) for this example gives d_{nf-ff} (433 MHz) = 0,11 m.

Figure I.4 shows the electric field resulting from a radiating antenna with three levels of input power and for two typical gain values. From the results we see that distance, power and antenna gain are important parameters that determine the exposure level. Figure I.4 also gives the near-field far-field boundary at the lowest frequency. It can be concluded that for the range of frequencies considered for intentional radiators (300 MHz to 3 GHz), and for the majority of exposure distance of interest (0,3 m to 2 m) always the far-field equations can be applied. For the exposure distance of 0,05 m (hand lamps), the near-field effects should be taken into account (Figure I.3). When looking at the impact of various power levels one can see that an input power of 20 mW always gives field levels well below the ICNIRP 1998 worst-case reference of 28 V/m. Also for an input power of 200 mW the reference level for the general public is not exceeded if the exposure distance is larger than approximately 0,2 m.

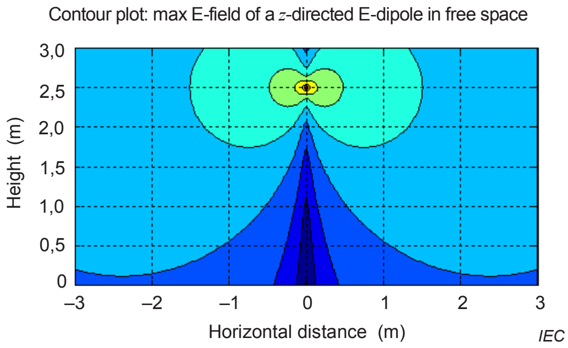


a) Exposure situation   b) Model

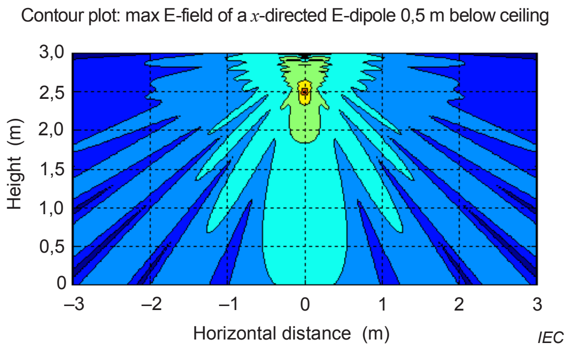
Figure I.1 – Luminaire with a transmitting antenna in a room



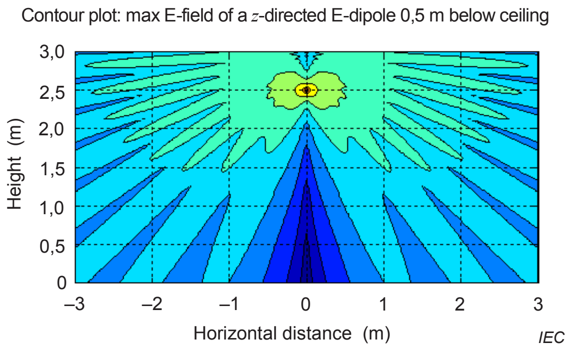
a) x-directed dipole 2,4 GHz free-space



b) z-directed dipole 2,4 GHz free-space



c) x-directed dipole 2,4 GHz, 0,5 m below a conductive plane



d) z-directed dipole 2,4 GHz, 0,5 m below a conductive plane

Figure I.2 – Impact of a conducting ceiling/plane

Hence, for the type of wireless technologies with intentional radiators mentioned in Table I.1, and based on an assessment using the worst-case ICNIRP reference level one may conclude that intentional radiators in lighting applications are compliant with the exposure requirements (reference levels) if the total maximum power fed into the antenna is less than 200 mW. It should be noted that these considerations are based on the application of reference levels, which are generally more conservative than basic restrictions [I.6][I.7][1].

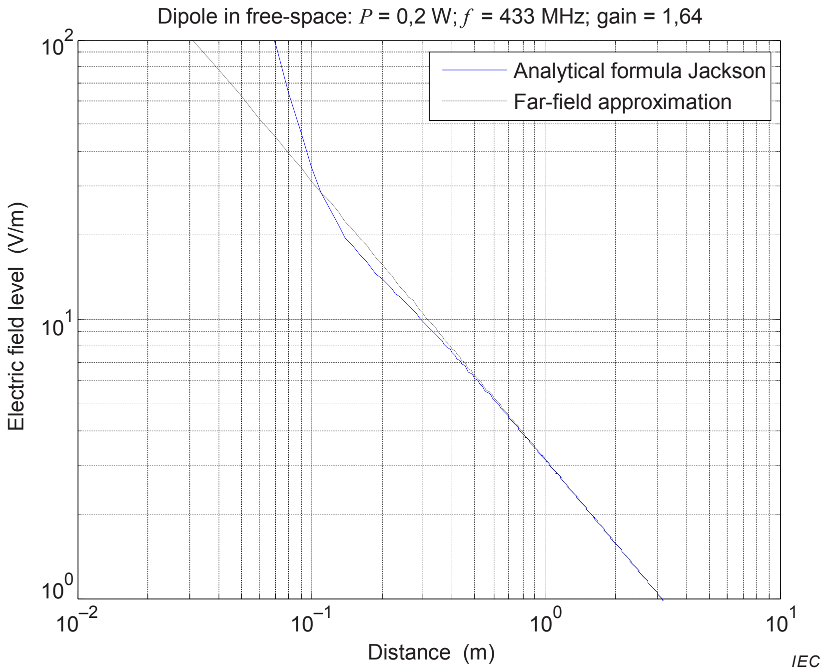
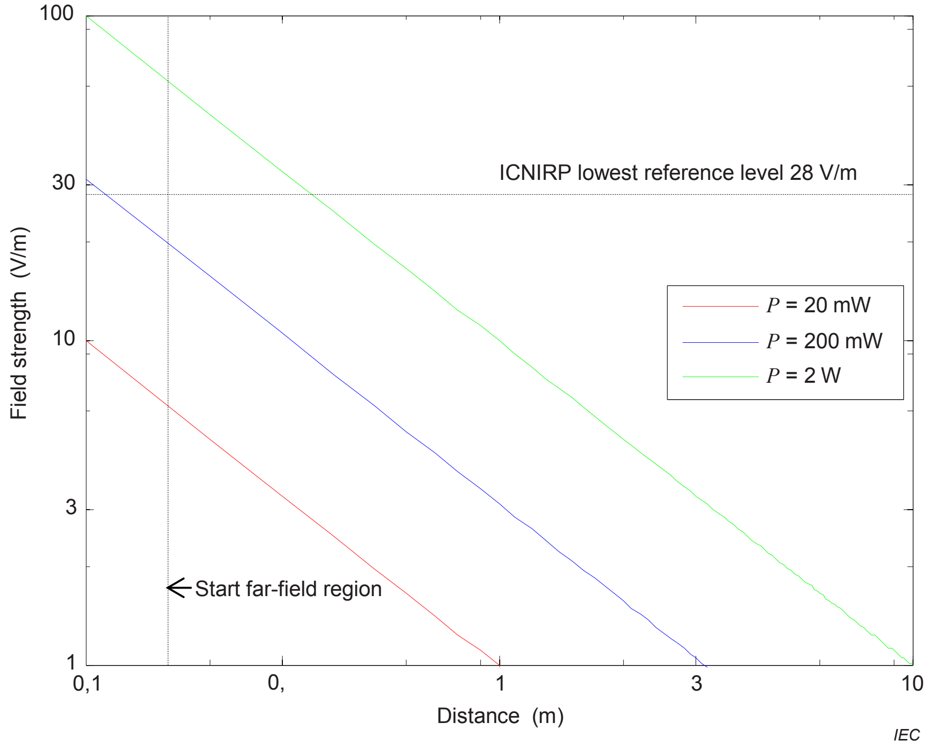
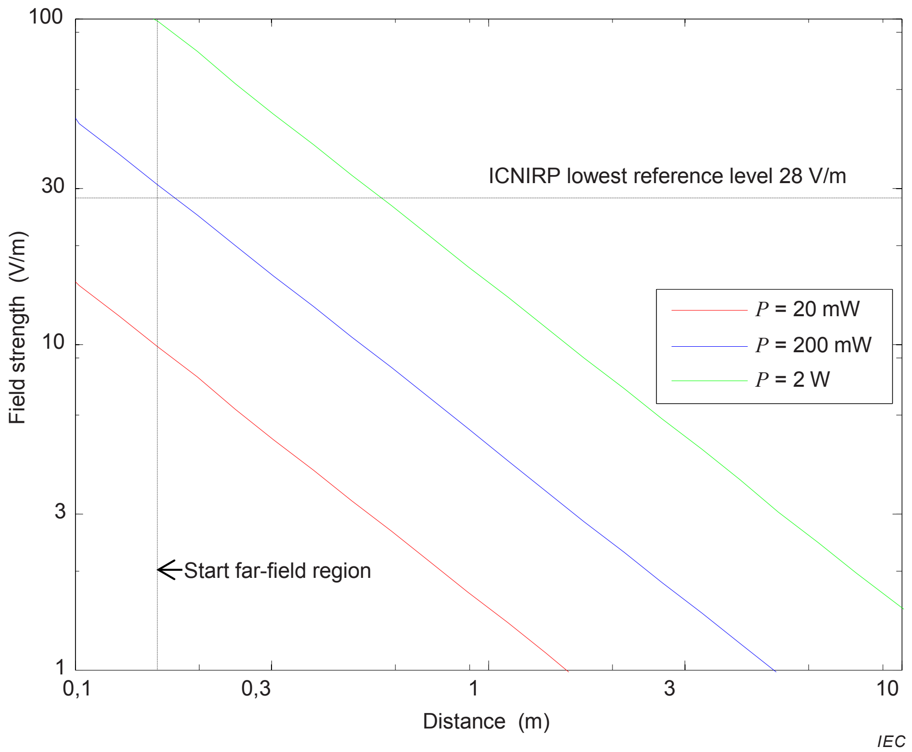


Figure I.3 – Electric field of a small electrical dipole: analytical formula vs far-field approximation



a) Antenna gain = 1,64



b) Antenna gain = 4

Figure I.4 – Electric field as a function of distance, antenna gain and input power (far-field approximation)

I.4 Exposure assessment approach

I.4.1 General

In general, an EMF assessment can be done by using either basic restrictions (BRs) or reference-levels/action-levels. In Clause I.3, a general assessment against reference-level has been discussed. An alternative and convenient assessment approach is based on determination of the total average radiated power of the intentional radiator. This so called 'low-power exclusion approach' is specified in IEC 62479. In this approach low-power exclusion levels are specified. If the actual total averaged (6 min) power at the input of an intentional transmitter $P_{\text{int,rad}}$ is below the exclusion level P_{max}, then the product complies by design without further testing.

$$P_{\text{int,rad}} < P_{\text{max}} \quad \text{(I.3)}$$

It can, for instance be easily derived from the 2 W/kg SAR basic restriction that applies for the head in both ICNIRP1998 and in IEEE C95.1-2005 in a 10 g voxel (volumetric pixel) of tissue. From this one can directly derive that a RF source of 20 mW just complies with this BR if all this power would be dissipated in this single voxel, which is very unlikely. Hence, the 20 mW low power approach is a convenient (but very conservative) approach, because one has simply to check the total radiated output power of a source.

I.4.2 Determination of average total radiated power $P_{\text{int,rad}}$

From Table I.1 one can see that some wireless transmitters radiate much less power than 20 mW, while others radiate more. For the low-power exclusion approach now we have to calculate the 6 min-average power transmitted by the intentional radiator.

When calculating the average total radiated power $P_{\text{int,rad}}$, one has to consider the maximum duty cycle of the intentional transmitted signal. The SAR-limit and the associated low-power exclusion level are based on a 6 min time averaging. If the intentional transmitted signals are time-limited e.g. pulsed continuously, then the power during the on-time of the signal can be much higher.

The average power can be calculated as follows:

$$P_{\text{int,rad}} = P_{\text{pulse}} \cdot D_{\text{c}} \quad \text{(I.4)}$$

where

$P_{\text{int,rad}}$ is the average power transmitted by the intentional transmitter,

P_{pulse} is the power transmitted by the intentional transmitter during the pulse (on time),

D_{c} is the duty cycle of the signal from the intentional transmitter, which is the product of the pulse duration T_{pulse} and the pulse repetition frequency PRF, i.e. $D_{\text{c}} = PRF \cdot T_{\text{pulse}} = T_{\text{pulse}} / T_{\text{rep}}$. See Figure I.5.

When applying this equation, one should be certain on how the transmit power of the wireless technology is defined (see Table I.1).

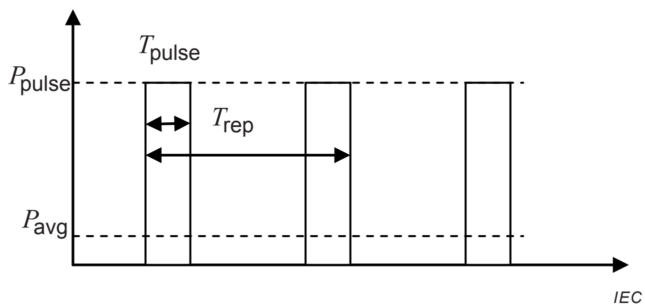


Figure I.5 – Impact of pulsed signals on the average exposure

EXAMPLE 1 Suppose the maximum transmitted power of a Zigbee signal is 5 mW, and the duty cycle is 5 % (see Table I.1). The maximum transmitted power corresponds to 100 % duty in conformance with ETSI EN 300-328. The average transmitted power in accordance with Equation (I.4) is then 0,25 mW.

EXAMPLE 2 WiFi has a theoretical duty cycle of 100 %. However the actual duty cycle of WiFi depends on many factors, and the 100 % level is truly exceptional [I.8]. As a result, the actual exposure levels are approximately a factor 1 000 smaller than what would be expected from modelling based on 100 % duty cycle. See Table 2 of [I.8].

I.4.3 Determination of the low-power exclusion level P_{max}

The basic EMF standard IEC 62479 gives low-power exclusion levels P_{max} based on the various basic restrictions that apply and the various categories of exposed humans (general public, occupational). See Table A.1 of IEC 62479:2010. For instance for ICNIRP 1998, general public exposure, the worst case low-power exclusion level is 20 mW for head and trunk. Compared with the possible power levels radiated by wireless sources (Table I.1), at first sight it seems that 20 mW-exclusion level of Equation (I.3) seems a very low value. For instance in case of a WiFi source, no compliance can be demonstrated by applying this low-power exclusion level, because the radiated power of a WiFi source may be between 100 mW and 1 000 mW, which is much larger than the 20 mW-exclusion level. However, there are methods to increase the low-power exclusion levels significantly. The methods to derive alternative (higher) low-power exclusion levels are given in the basic EMF standard IEC 62479.

It is readily seen from the field calculations presented in Figure I.3 that the field strength decays with $1/d$, and that for larger exposure distances it becomes extremely improbable that the 20 mW power from a transmitter is captured by a single voxel of 10 g. Also in the basic EMF standard IEC 62479, alternative low-power exclusion levels have been derived as a function of exposure distance and as a function of antenna type and wireless technology.

A more accurate/specific relaxation formula can be derived by applying the SAR-estimation formulas derived in [I.10]. In this paper, the SAR-estimation formula is derived with antenna properties, distance and frequency as parameters. Annex B of the basic EMF standard IEC 62479:2010 gives the calculation method for alternative low-power exclusion levels as a function of distances and antenna type for exposure distances between 0,05 m and 0,25 m. These alternative values are based on studies by Ali et al. [I.9]. Figures 3 and 4 of [I.9]show some results as a function of frequency and for different types of antennas. For example, at 900 MHz, for different types of antennas, one can apply safely a low-power exclusion level of 150 mW at a distance of 0,25 m. This is a relaxation of a factor 7,5.

EXAMPLE For WiFi technology, Table B.1 of IEC 62479:2010 gives the following alternative exclusion levels for an averaging mass of 10 g:

– distance 0,05 m: P_{alt} = 32 mW
– distance 0,25 m: P_{alt} = 328 mW.

I.5 Multiple transmitters in a luminaire

The way of adding power depends on the type of source. IEC TR 62630 is a technical report which gives guidance on how to evaluate exposure from multiple sources. In case of k correlated sources, the upper bound of the SAR is determined by (see 6.5.2.22 of IEC TR 62630 [I.11]):

$$SAR_{tot} \le \left(\sum_{k=1}^{N} \sqrt{SAR_k} \right)^2 \quad (I.5)$$

In case of lighting equipment with multiple intentional radiators, the contributions from the individual intentional transmitters are generally not correlated and therefore the SAR or power densities of the k individual sources are added in a linear way as explained in 6.4 of IEC TR 62630 [I.11]:

$$SAR_{tot} = \sum_{k=1}^{N} SAR_k \quad (I.6)$$

As SAR is directly linked with the low-power exclusion levels, also the linear summation applies for the total power of the k individual uncorrelated sources. Hence, the total radiated power of all the intentional radiating sources must be added in a linear way relative to each of the low-power exclusion levels applicable for that wireless technology (frequency, antenna). The low-power exclusion compliance criterion of Equation (I.3) then becomes for a total of N uncorrelated transmitters:

$$\sum_{k=1}^{N} \frac{P_{\text{rad}}^{k}}{P_{\text{max}}^{k}} < 1 \qquad \text{(I.7)}$$

In Annex D it has been shown that the total power emitted by the unintended radiated emission in the frequency range from 100 kHz up to 300 MHz is negligible. Therefore, the contribution of the unintended radiation can be ignored in Equation (I.7).

I.6 Exposure to multiple luminaires

The EMF exposure assessment is limited to a single luminaire. Multiple luminaires are not addressed. Reasons are:

- EMF product standards always apply for a single product, not for an installation;
- close to a luminaire (e.g. 0,3 m) the contribution from this luminaire is dominant; this can be demonstrated by modelling;
- it should be noted that the additional gain due to installation of a single luminaire is taken into account.

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[11] CISPR 16-4-2:2003[2], *Specification for radio disturbance and immunity measuring apparatus and methods. Part 4-2: Uncertainties, statistics and limit modelling – Uncertainty in EMC measurements*

[12] IEC 62226-2-1:2004, *Exposure to electric or magnetic fields in the low and intermediate frequency range – Methods for calculating the current density and internal electric field induced in the human body – Part 2-1: Exposure to magnetic fields – 2D models*

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[2] First edition. This edition has been replaced by CISPR 16-4-2:2011 and CISPR 16-4-2:2011/AMD1:2014.

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